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by

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Water and Soil Division
Ministry of Works and Development
Christchurch

WELLINGTON 1980

Rakaia water use and irrigation development by D. R. Maidment, W. J. Lewthwaite and S. G. Hamblett, Water and Soil Division, Ministry of Works and Development, Christchurch.Water and Soil Miscellaneous Publication No. 19. 1980. 47p. ISSN0110-4705.

More than 200,000 ha of potentially irrigable land is situated adjacent to the Rakaia River and overlays extensive groundwater aquifers. Of this land, 35,000 ha is currently irrigated and a 65,000 ha irrigation development to cost $50 million is currently being considered. At present less than 0.5% of Rakaia River mean annual flow, and 3–12% of estimated annual groundwater recharge are abstracted for irrigation. Irrigation demands are most likely to be high in November and December when Rakaia River flows are also high but significant irrigation demands will also occur from January to March when river flows are falling and salmon are migrating up the river to spawn. About 20,000 angling licences are sold annually in North and Central Canterbury, and a recent survey rates the Rakaia River as the second most important fishery in this region with 40% of the survey respondents visiting the Rakaia River at least once a season. There is potential for augmenting low flows in the Rakaia River through management of Lake Coleridge. Irrigation abstractions appear to have little effect on the pattern of floods and freshes in the Rakaia River but could be more significant during low flow periods. Adverse environmental effects in the river are most likely to occur in the lower reaches near the coast where the river is most braided, seepage losses to groundwater and irrigation abstractions have occurred upstream, and the greatest number of fish species are affected. No evidence exists at present that irrigation abstractions within the current water allocation plan would cause major adverse environmental effects. Analysis indicates that utilization of groundwater in the Rakaia region is economic if it can be pumped from 60 m or less, even at quite high energy prices. Irrigation using river water can also be economically justified if the rate of development is rapid.

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Preface

During 1978/79, a co-operative research project on Rakaia water and related resources was carried out by the Water and Soil Division of the Ministry of Works and Development, Christchurch, in collaboration with other agencies of national and local government and private enterprise.

In view of possible large-scale use of Rakaia water resources for irrigation, the objective of the project was to assess the available water and related resources, document the uses currently being made of those resources, and estimate the scope and implications of possible irrigation development. This report summarises the results of this project.

Separate reports have been produced by the collaborating study groups to describe more fully the results of their research. In some cases these are interim reports on continuing research programs but in most cases they represent completed work on specific topics carried out during the study period. Those reports currently available are:

Davis, S. 1979: Fish and fishery values of the Rakaia River – a preliminary report. Internal Report Fisheries Research Division, Ministry of Agriculture and Fisheries, Christchurch, NZ. 55p.

Douglass, M.; Robson, S.; Wilson, A.; Worth, M. 1979: Rakaia water use and irrigation development: recreation, landscape, planning. Joint report by Gabites, Alington and Edmondson, consultants; and MWD Environmental Design Section, Ministry of Works and Development, Christchurch, NZ. 98p.

Ibbitt, R. P. 1979: Flow report for Rakaia River at Gorge, site 68502 for the period 1957-78. *Water and Soil Science Centre Report WS11.* Ministry of Works and Development, Christchurch, NZ. 52p.

Philpott, W. J. L. 1980: Rakaia water use and irrigation development: matching supply and demand for water from the Rakaia River. *Water and Soil Irrigation Report WS114.* Ministry of Works and Development, Christchurch, NZ. 41p. & Appendices.

Other reports are in preparation. Further information on these reports may be obtained from:

The Technical Information Officer,
Water and Soil Division,
Ministry of Works and Development,
PO Box 1479,
CHRISTCHURCH (Tel. 791 200)

Acknowledgements

The authors of this report wish to acknowledge the contributions of the many groups and individuals who participated in the research. First among these are the other members of the research team, Paul Hutchinson and John Philpott, and, for a period, Richard Broadhead, Chris Power, and Lee Weston. Paul Hutchinson, in particular, assisted greatly in the preparation of this report.

Next, those who conducted companion studies: Rob Burden, Graeme Davenport, Maurice Duncan, John Fenwick, Murray Hicks, Richard Ibbitt, David Scott, Stephen Thompson and Hugh Thorpe of the Christchurch Science Centre; Malcolm Douglass and Sue Robson of Gabites, Alington and Edmondson, Consultants, Christchurch; Alec Wilson and Marion Worth of the MWD Environmental Design Section, Christchurch; and Sally Davis, Don Le Page, Bob McDowall, Ian Ritchie and Paul Sagar of the Ministry of Agriculture and Fisheries, Christchurch.

Finally, those whose advice and counsel kept us on the track: Ken Mitchell, Herb Morriss, Peter Reynolds and Alan Stevens of the MWD; and those who provided us with information: Mike Bowden and John Hamilton of the North Canterbury Catchment Board; Bert Stringer and Ray Walsh of the South Canterbury Catchment Board; Trevor Webb of DSIR Soil Bureau; and staff of Winchmore Irrigation Research Station; Ministry of Agriculture and Fisheries, Ashburton; Ministry of Energy, Christchurch; and Ministry of Works and Development, Wellington.

Clearly the list could go on much further. To all we offer our thanks.

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1 Introduction

In 1973, the government announced a revised policy for encouraging the development of community irrigation schemes throughout the drought-prone areas of New Zealand. The two largest schemes envisaged as being promoted under this policy are the Lower Rakaia and Central Plains schemes, located on either side of the Rakaia River.

Almost 200,000 ha of agricultural land would be covered by these schemes, 40% of the potentially irrigable land in New Zealand. The diversions of water needed to supply this irrigation are comparable to those of major hydroelectric power developments undertaken in the country. The Lower Rakaia scheme alone is estimated to cost $50 million.

Even if these major schemes are not undertaken in the near future, the constant economic pressure on agriculture to produce more from a fixed land resource makes it likely that irrigation development by individual farmers and in smaller community irrigation schemes will continue to expand in the region. As the Rakaia River and its associated groundwater aquifers are the water resources having the greatest potential for supplying irrigation water in the Canterbury Plains it is very likely that these resources will be under increasing pressure in future years to support irrigation development, irrespective of the outcome of major scheme initiatives.

In former times rivers which flowed out to sea unutilised were regarded as wasted (Public Works Department 1945) but in recent years attitudes have changed, with an increasing awareness of the value of our natural water resources being embodied in legislation. It is no longer sufficient to make simple assumptions about the availability of water because it is now necessary for the National Water and Soil Conservation Authority along with the regional water boards to control the use of natural water with due regard for the needs of fisheries, wildlife, and recreation as well as all other water uses.

The Rakaia River currently supports a range of other uses besides irrigation: a major salmon run occurs from January to April, attracting some thousands of fishermen; river water is already diverted for power production at Lake Coleridge and further power developments are envisaged; jet-boaters, picnickers and swimmers use the river for recreation; rural water supplies are drawn from it, and the river provides a habitat for many fish and bird species.

The National Water and Soil Conservation Authority and the regional water boards jointly have the function and power "to co-ordinate all matters relating to natural water so as to ensure this national asset is available to meet as many demands as possible and is used to best advantage of both the country and the region in which it exists in the course of nature" (Water and Soil Conservation Act 1967). This is obviously a very complex task in the case of the Rakaia catchment.

The present study was initiated recognising the widespread economic, environmental and social effects of the major irrigation developments proposed for the Rakaia area. Its purpose is to draw together the facts which exist on the resources themselves, the uses currently being made of these resources, and the scope and implications of possible irrigation developments.

This report surveys the available information on these subjects, and provides some interpretation of that information to identify the facts which have been determined to date. On topics where insufficient research has been done to make accurate assessments, the available results are presented without attempting to draw definite conclusions from them.

No such study starts in a vacuum and, in this respect the comprehensive report on the Rakaia water resources by Stephen (1972) is a milestone. His careful analysis of the available data is a foundation upon which later studies, including the present one, can build with confidence. Stephen's report followed that of Dalmer (1971) on the Waimakariri River, and studies of other Canterbury water resources have been carried out by Bowden (1974, 1977) and Walsh (1975). Huber (1973) surveyed the water requirements for expanded irrigation development on the Canterbury Plains.

The present study focuses on the area where Rakaia water is mainly utilised (Fig. 1.1) and does not consider in detail the mountain catchment area from which the water is derived. This is justifiable in the case of the Rakaia because the flow from all the mountain catchment is concentrated at the Gorge and few man-induced alterations to the natural flow pattern at the Gorge are likely to occur in the foreseeable future apart from the management of Lake Coleridge as a storage reservoir which is considered in section 4 of this report.

The study area delineated in Fig. 1.1 has been chosen as the area within which surface water or groundwater resources derived from the Rakaia River could be used for irrigation. This covers 3,600 km² from the Ashburton River in the south to the Waimakariri River in the north, and from the Rakaia Gorge and the line of the Alps foothills at approximately the 330 m contour in the west to the coast in the east excluding Lake Ellesmere and Christchurch and its environs. Naturally this is not a rigid boundary as specialised studies have focused on smaller portions within the study area and others have gone outside it. Nevertheless it indicates the region of primary interest For convenience this delineated study area is also referred to as the Rakaia region in this report.

The body of the report comprises three parts: an inventory of the water and related resources of the Rakaia region (section 2), a survey of the present use being made of these resources and how that use has developed over the years (section 3); and an examination of particular irrigation development options and the social, environmental and economic effects of these (section 4).

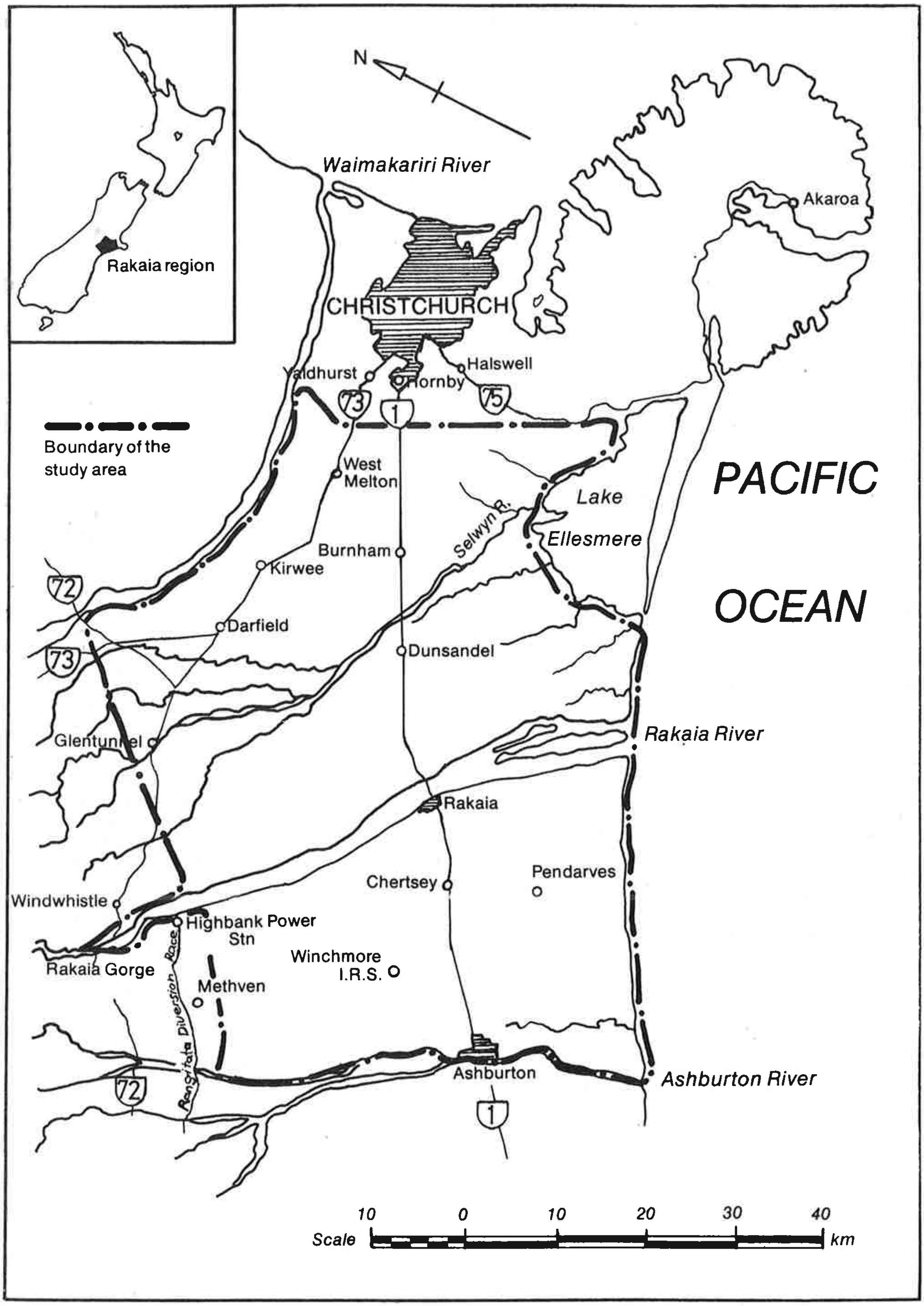


Fig. 1.1 Rakaia region study area

2 Inventory of the Water and Related Resources

2.1 Climate

The climate of Canterbury is dominated by the effect of the Southern Alps as they intercept weather systems approaching New Zealand. The Canterbury Plains receive less rainfall than most other parts of New Zealand, because westerly air flows lose their moisture by precipitation as they are lifted over the Alps and the plains are left in a rain shadow. The plains are often traversed by dry north-westerly, Foehn winds bringing low humidity and raised temperatures. South-westerly air flows and associated cold fronts bring much of the plain's rainfall. Heavy rain usually results from a depression over the region or just off the east coast.

Droughts occur annually over a major part of the region. At Winchmore Irrigation Research Station a water balance study of dryland pasture (Rickard and Fitzgerald 1969) showed that during the irrigation season (September to April) agricultural droughts lasting longer than 20 days occurred in 30 of the 41 years examined. (Agricultural drought exists when the soil moisture level in the root zone is below wilting point for grass).

The region receives between 1900 and 2100 hours of sunshine per year. Average daily total radiation is about $14MJ/m^2$ and ranges from $6MJ/m^2$ in June to $22MJ/m^2$ in December.

The variation in air temperature over the year at Winchmore is shown in Fig. 2.1. The highest monthly average temperature occurs in January, a month later than the time of maximum radiation, because of the inertia effect of the heating of the earth. Compared with continental land masses, the 11°C variation in monthly mean temperature over the year is quite small, but within any month temperature varies over a much wider range of 20°C or more. As Mandel (1974) stated: "In Canterbury one may experience all the four seasons during 24 hours". Frosts occur frequently from late autumn to early spring and occasionally severe late spring

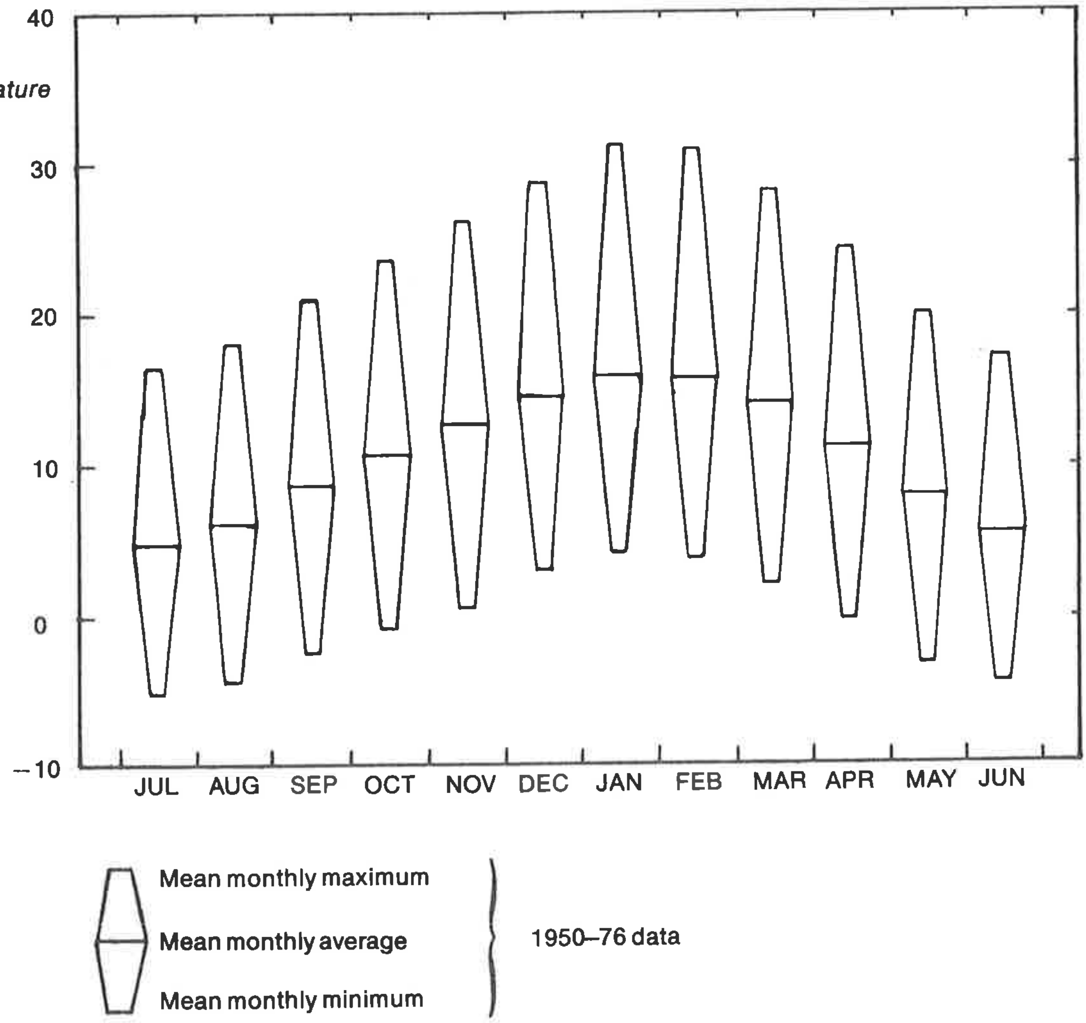


Fig. 2.1 Temperature at Winchmore
(Source: Rickard 1978)

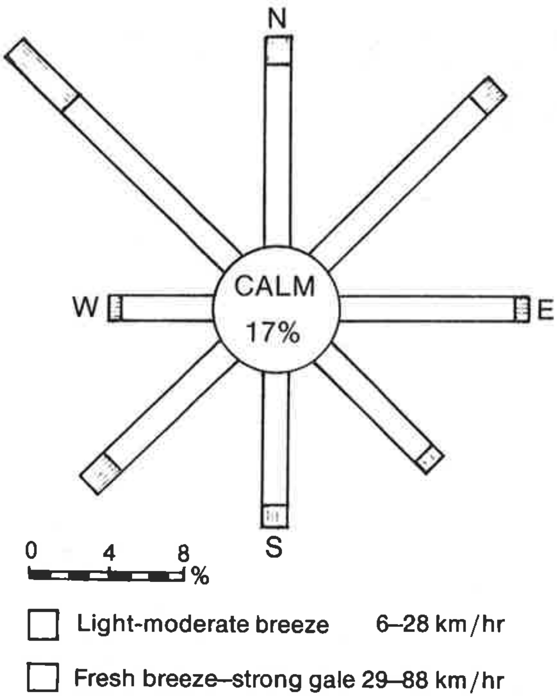


Fig. 2.2 Distribution of surface wind direction at Ashburton *(Source: N Z Met. Service unpub. data, 1938–48)*

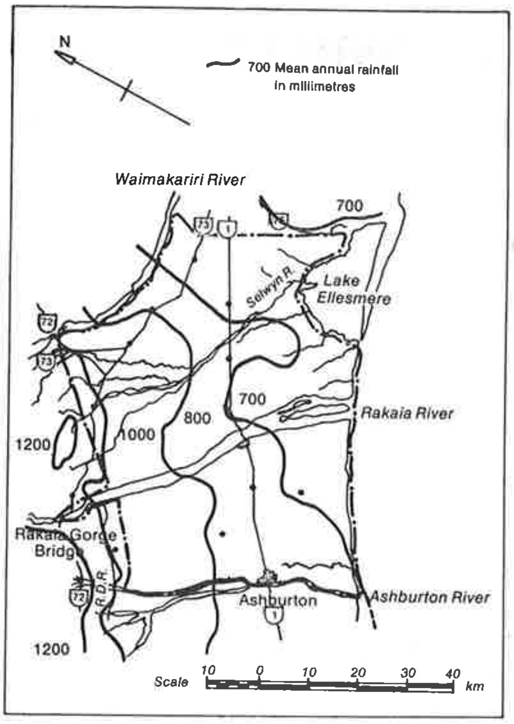


Fig. 2.3 Mean annual rainfall contours for 1941-70 data *(Source: N Z Met. Service 1973)*

frosts damage crops.

The wind regime at Ashburton is shown in Fig. 2.2. The predominant wind there is the north-westerly, which is particularly important in the summer when strong, warm, north-west winds cause much drier conditions than temperature and rainfall would indicate. The average annual wind run at Winchmore and Highbank is 290 km/day and in early summer there are frequently north-west winds with runs of over 500 km/day for several days on end.

Considerable variations in wind regimes occur across the Rakaia region. Near the coast sea breezes are common. Near the Rakaia and Waimakariri Gorges, north-westerlies can be extremely strong, at times raising great dust clouds from the river beds.

The mean annual rainfall varies from less than 700 mm/yr near the coast to 1000 mm/yr at the foothills (Fig. 2.3). The distribution of mean monthly rainfall throughout the year is also fairly uniform but the average figures mask the great variations in rainfall that can occur from month to month in any year. Fig. 2.4 shows that monthly rainfalls of less than 10 mm and more than 240 mm have been recorded with little apparent seasonal pattern. The large temporal variation in rainfall is the climatic variable dominating agricultural production differences from year to year and is the most significant factor in the agricultural water demand analyses considered in section 4.

Snowfalls are rare near the coast and the snow usually melts within a few hours. Near the foothills snowfalls are likely for several days each year in winter and spring. Typically there are two or three hailstorms each year in spring and summer.

Monthly average potential evapotranspiration exceeds monthly average rainfall at Winchmore for the six months October to March, and varies between an average of 0.5 mm/day in July and 3.2 mm/day in January. Pan evaporation records show great variation from day to day with peaks of up to 20 mm/day evaporation during strong north-westerly conditions. Monthly pan evaporation records show more variation than results from the Thornthwaite method of estimating evaporation but less variation than monthly rainfall.

2.2 Water Resources

Rivers

The tributaries from the 2640 km^2 upper Rakaia catchment have all joined the main stream of the Rakaia River by the time it reaches the Gorge. With a mean annual flow of 196 m^3/s at this point the Rakaia is the largest river flowing across the Canterbury Plains. (1 m^3/s = flow rate of 1 cubic metre per second, 1 cumec). Monthly mean flows in the Rakaia have a seasonal pattern with the minimum in July and the maximum in November (Fig. 2.5 and Table 2.1). Extreme instantaneous flows at the Gorge ranging from 77 m^3/s to 3545 m^3/s have been reported for the period 1957-78 (Ibbitt 1979).

As shingle is continually moving down the river, the bed at the water level recorder site is unstable. Consequently, the rating curve used to convert water level records into flow rates also changes, and must be regularly checked by field measurement. Ibbitt (1980) made a retrospective analysis of the flow records at the Gorge site from 1957-78. He concluded that the rating curve changes vertically 100 mm or more on average three times per year, with most changes occurring from October to December as a result of spring floods. He also found that for this period Rakaia Gorge mean annual flows correlate much more closely with mean annual rainfalls from gauges on the West Coast near Hokitika than

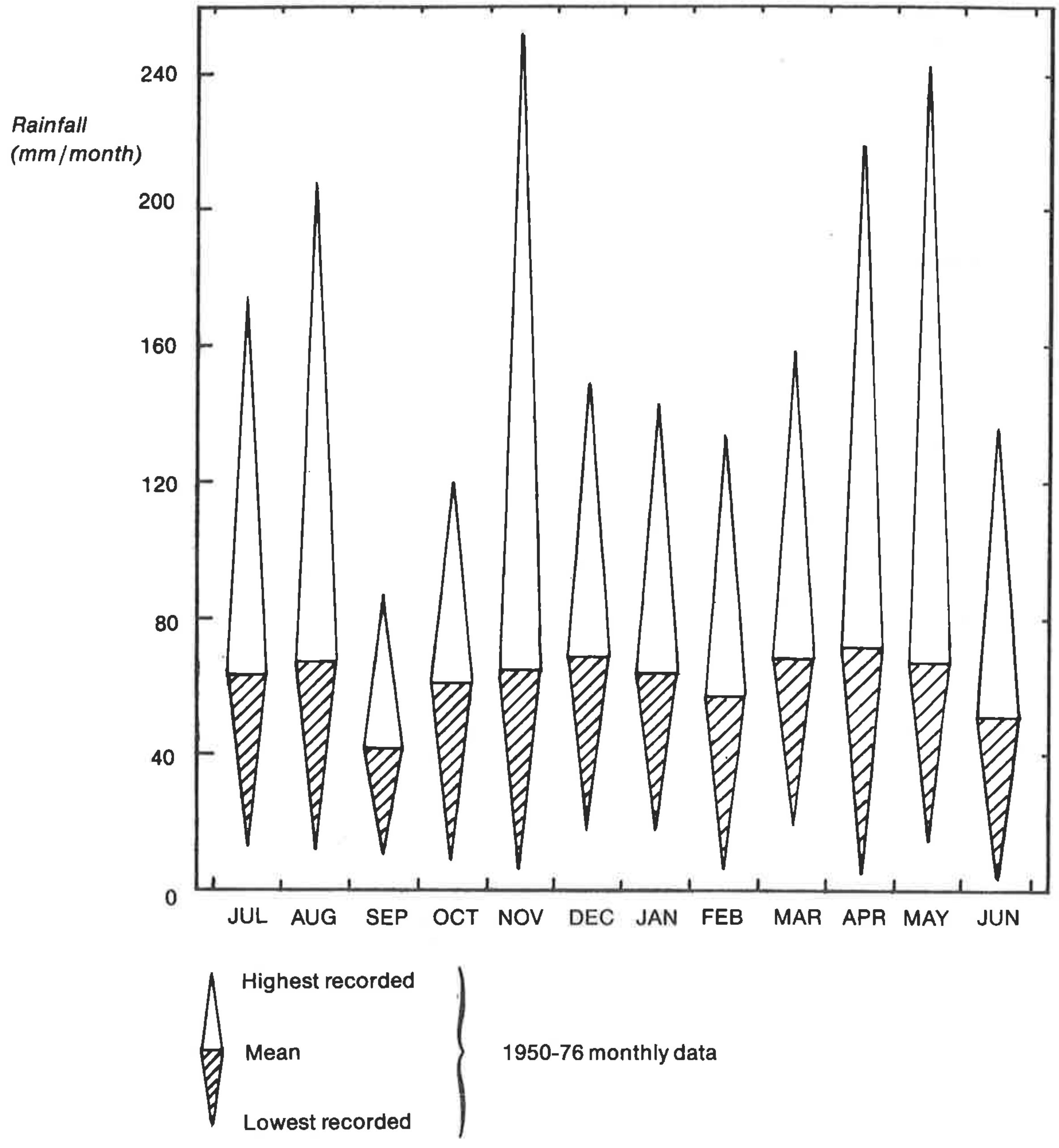


Fig. 2.4 Monthly rainfall distribution at Winchmore
(Source: Rickard 1978)

with rainfall records taken from within the Rakaia catchment itself at low elevations. This occurs because the catchment is widest at the main divide of the Southern Alps and the bulk of the runoff results from precipitation at high elevations over the main divide. The pattern of this precipitation is closer to West Coast rainfall than to rainfall in the rain shadow areas to the east of the main divide.

The flow data for the Gorge station, 1957-78, from Ibbitt's analysis are given in Table 2.1. These are the most accurate produced to date and supersede earlier figures. These data could be further refined at such time as better analysis methods become available.

The variation of flow along the channel deduced from concurrent gaugings in July 1979 is shown in Fig. 2.6. This figure shows the degree of management control of Rakaia River flows in that, of the flow at the coast of 117 m^3/s, 59 m^3/s was discharged from power stations, and 23 m^3/s from the Wilberforce River which is partially controlled by a diversion race into Lake Coleridge.

Concerning the migration of salmon to spawning grounds around Glenariffe, Fig. 2.6 shows that the Rakaia River above the Wilberforce River confluence has the lowest flows on the migration passage up the river, and that very considerable reductions in flow below the Gorge would have to occur before flows there become as low as those naturally occurring above the Wilberforce River confluence (Hicks pers. comm.).

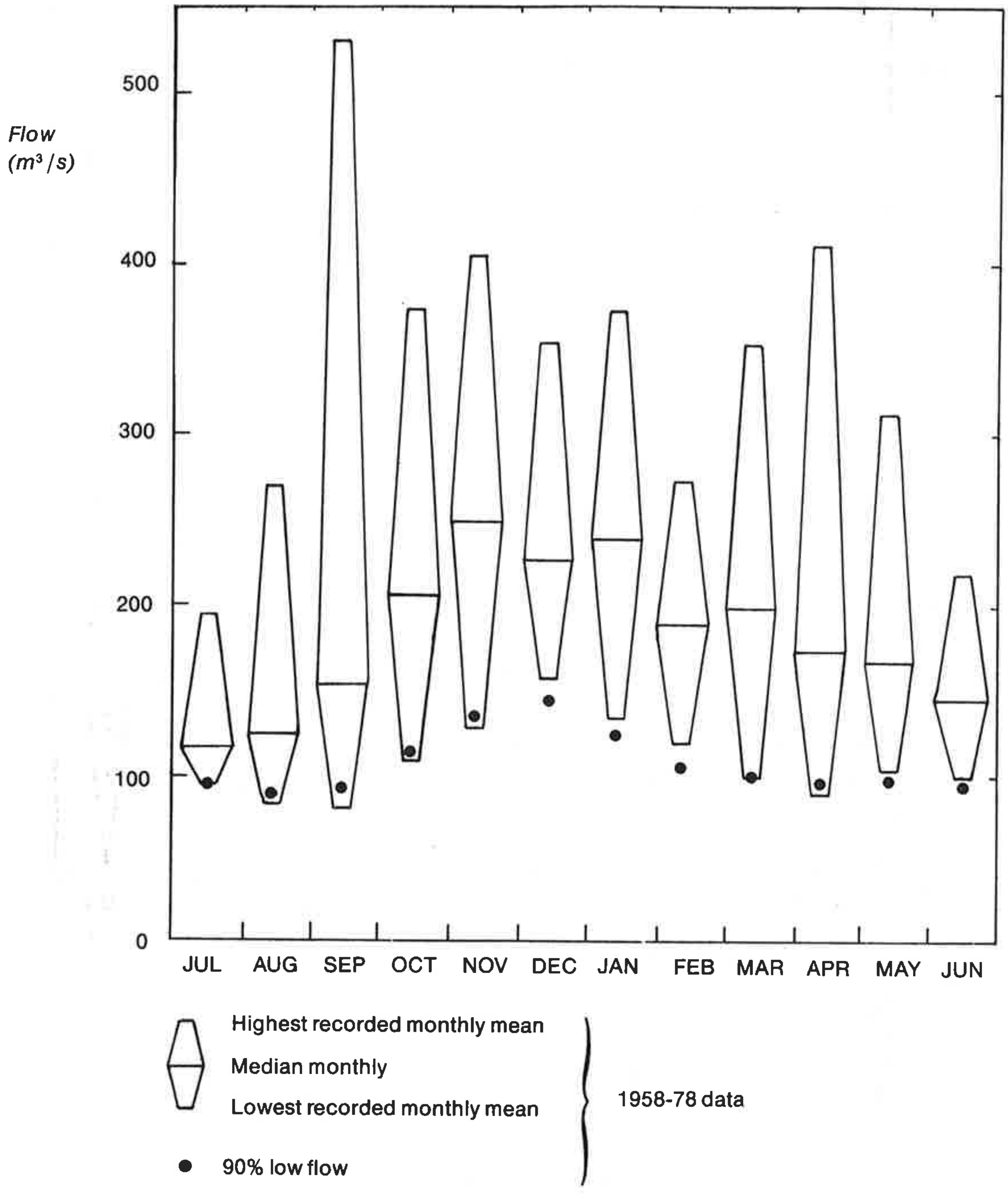


Fig. 2.5 Monthly flow distribution for Rakaia River at Gorge
(Source: Ibbitt 1979)

By means of simultaneous flow gaugings at the Gorge and State Highway 1 bridges, Stephen (1972) derived a relation with correlation coefficient 0.96 between the flows in m^3/s at these points as:

$$Q_s = 0.83Q_g + 9.6; \qquad 100 \leq Q_g \leq 200 \quad \ldots (2.1)$$

where Q_s is the flow at State Highway 1 and Q_g is the total of the Gorge and Highbank flows. This relation implies that losses increase as the flow increases. For a flow of 200 m^3/s, the loss is 24 m^3/s.

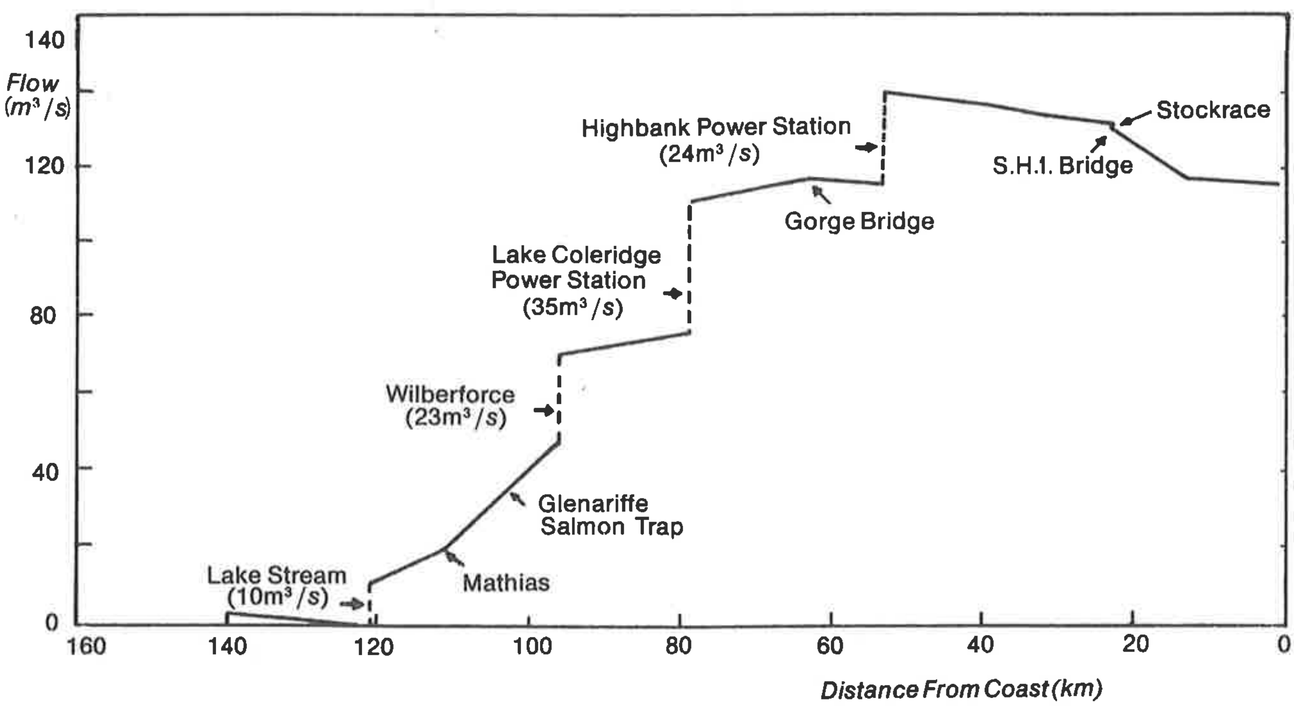
Losses in the reach from State Highway 1 to the coast have been gauged at 15.2 m^3/s and 6.7 m^3/s when flows at State Highway 1 were 138 m^3/s and 177 m^3/s, respectively. The average slope of the river from the Gorge to the coast is 4m/km.

The river flows in a braided channel on a bed which gradually widens downstream (Fig. 2.7) until it is almost 5km wide at the coast. Measurements from aerial photographs of channel widths at intervals along the river demonstrate that the total width of flow shows little trend as the river passes across the plains apart from narrowing near the Gorge and the coast. The number of braids at any section increases going downstream from an average of 10 near the Gorge to 20 near the coast (at a flow of 120 m^3/s). The average braid width decreases accordingly going downstream. Above the Gorge the flow is concentrated in a small number of channels across a wide, dry bed (Hicks pers.comm.).

The Rakaia River enters the sea through an opening in a sand spit behind which a lagoon is ponded. The position of the opening fluctuates along the coastline. Between the State Highway 1 bridge and the sea, the river is braided into

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
58	***	***	***	***	286	148	96	***	***	226	242	306	***
59	138	150	150	152	125	174	113	103	176	166	299	341	174
60	274	254	222	127	159	154	122	186	212	208	200	175	191
61	165	232	279	245	106	116	110	124	101	205	266	166	176
62	368	146	134	118	290	185	196	171	176	281	323	205	217
63	172	240	191	145	237	193	141	156	225	161	229	176	188
64	349	173	260	152	312	172	170	165	145	166	165	330	214
65	***	235	141	123	147	169	114	107	117	157	369	320	***
66	354	274	150	270	167	125	112	100	109	120	233	256	189
67	293	231	356	414	201	113	176	247	127	218	406	355	262
68	248	250	251	193	262	134	126	146	135	318	251	206	210
69	183	145	205	189	151	104	105	102	388	145	131	292	178
70	242	125	213	205	104	122	113	270	532	189	246	232	216
71	148	125	102	93	105	221	100	92	150	340	189	221	157
72	212	127	246	167	207	116	117	112	226	374	406	253	214
73	161	122	123	222	174	144	96	106	158	251	399	194	179
74	180	202	184	343	117	120	144	126	120	219	253	160	180
75	256	218	247	357	308	180	144	186	194	239	263	228	226
76	265	180	172	109	155	211	116	104	105	142	156	338	171
77	374	217	194	139	109	102	96	84	82	109	233	223	163
78	245	150	213	247	314	159	134	222	246	247	253	205	220
Min	138	122	102	93	104	102	96	84	82	109	131	160	157
Mean	238	190	202	201	192	150	126	145	186	213	262	247	196
Max	374	274	356	414	314	221	196	270	532	374	406	355	262

Table 2.1 Rakaia River monthly mean flows at Gorge for 1958 – 78 (m^3/s) *** indicates missing data
(Source: Ibbitt 1979)



---- indicates inflow as labelled

Positive slope indicates additions to flow from groundwater and minor tributaries
Negative slope indicates losses to groundwater

Conditions as at July 1979

Fig. 2.6 Variation in flow along the Rakaia River
(Source: Hicks pers. comm.)

Fig. 2.7 Braided channel of the Rakaia River
Looking N.W. towards Mt Hutt from below S.H.1 Bridge (Centre)

V. C. Browne & Son

a larger number of channels than upstream and contains two islands. During the winter of 1979, field measurements of a major channel in this braided reach showed that its location was unstable even though the flows in the river were at their seasonal low during this period.

The natural flow of the Rakaia River is supplemented by water discharged through Highbank Power Station from the Rangitata Diversion Race. This race was constructed between 1935 and 1945, diverting water north from the Rangitata River to supply the Mayfield-Hinds, Valetta and Ashburton-Lyndhurst irrigation schemes. The 67 km long earth channel, designed to carry 31 m^3/s (1000 ft^3/s), follows the 350 m (1150ft) contour at the top of the plains, passing under eight rivers by inverted syphons. During the winter all flow in the Race is discharged through the Highbank Power Station to the Rakaia River (section 3.4), while in the September to April period irrigation takes first priority and only surplus water is discharged at Highbank.

The other significant surface water resource in the region is the Selwyn River, and its tributaries the Hawkins, Waireka, and Hororata Rivers, which rise in the foothills of the Central Plains area. The total Selwyn catchment area is 678 km^2. Flows recorded on the Upper Selwyn River at Whitecliffs, where the catchment area is 164 km^2 (24% of total), averaged 3.2 m^3/s from 1965 to 1977 with a maximum recorded flow of 186 m^3/s. Average flows are highest in the spring and lowest in the summer and autumn. As the Selwyn River flows across the Plains substantial seepage to groundwater occurs such that the river bed is dry over a long distance in its middle reaches for most of the year, especially during summer. The river is perennial in its lower reaches and flows into Lake Ellesmere.

Groundwater

In recent years both the North and South Canterbury Catchment Boards have directed increasing activity towards quantifying the flow of groundwater which moves through the aquifers under the Canterbury Plains on its way to the sea.

The aquifers are recharged with downward-draining, excess soil moisture and with surface flow losses which percolate through stream beds and banks to join the groundwater. Neither of these quantities can be measured directly, therefore, they must be deduced.

A great range of activities is involved, some of which were started many years ago. They include:

* Recording and analysing bore-hole data;
* Collating such data with geological information;
* Observing water table levels and piezometric pressures;
* Deducing aquifer properties from test-pumping data;
* Deducing flow rates using trace element data;
* Estimating rainfall and irrigation effects on drainage through the soil and subsoil;
* Estimating river gains and losses by making concurrent flow gaugings at several places on a river;
* Constructing and refining computer models to simulate the observed behaviours of the groundwater systems;
* Using the models to predict the response of the groundwater system to altered inputs and withdrawals.

Estimates indicating the average rates of recharge of the groundwater under the plains between the Waimakariri and the Ashburton Rivers are listed in Table 2.2. They show a range of 20 to 70m^3/s. This range highlights the difficulty of accurately assessing these groundwater resources.

Source of Information		Drainage From Rainfall and Irrigation (m^3/s)	Nett Rivers Contribution (m^3/s)	Total (m^3/s)
Waimakariri-Rakaia				
Hunt & Wilson	(1974)	—	—	41
Mandel	(1974)	5-7	7-11	12-18
Donaldson	(1977)	16-19	13-16	29-35
Bowden (pers. comm.)	(1979)	3-8	22	25-30
Rakaia-Ashburton				
Spence et al.	(1974)	not estimated	16-20	16-20
Mandel	(1974)	—	—	8-12
Thorpe	(1979)	10-16	15	25-31

Table 2.2 Groundwater recharge estimates

The water table slopes down towards the coast (Fig. 2.8). As flow occurs perpendicular to the contours shown, the Rakaia River can be seen to be contributing to groundwater flow on both sides of the river below the State Highway 1 Bridge. As the slope of the land surface is greater than that of the water table, the depth to groundwater increases progressively with distance from the coast. The gravels which underlie the plains are strongly stratified and form a complex series of aquifers which often have high yields and transmissivities near the coast and close to the rivers (transmissivity is a measure of the ease of flow through a groundwater aquifer). Transmissivities tend to decrease with increasing depth and also with distance from the coast and rivers. Most wells with high yields sufficient for irrigation occur within 30 km of the coast and are less than 40m deep. A few shallow high yielding wells exist further inland near the rivers in what is probably post-glacial alluvium.

Lakes

There are two significant lakes within the catchment, Lake Heron and Lake Coleridge. Lake Coleridge storage is used for hydro-electric power generation.

	Surface Area (ha)	Existing Storage Range (m)	Existing Storage Volume (m^3)
Lake Coleridge	3640	3.95	1.42×10^8
Lake Heron	673	—	—

The natural inflow to Lake Coleridge has been augmented by diversions from the Acheron, Harper and Wilberforce Rivers with a mean annual flow of 20 m^3/s (Ibbitt 1979). The natural lake outflow is controlled by a radial gate which is normally kept closed. The existing manageable storage volume is equivalent to 80 days inflow at current diversion rates. The use of water from Lake Coleridge for power generation is described in section 3.4.

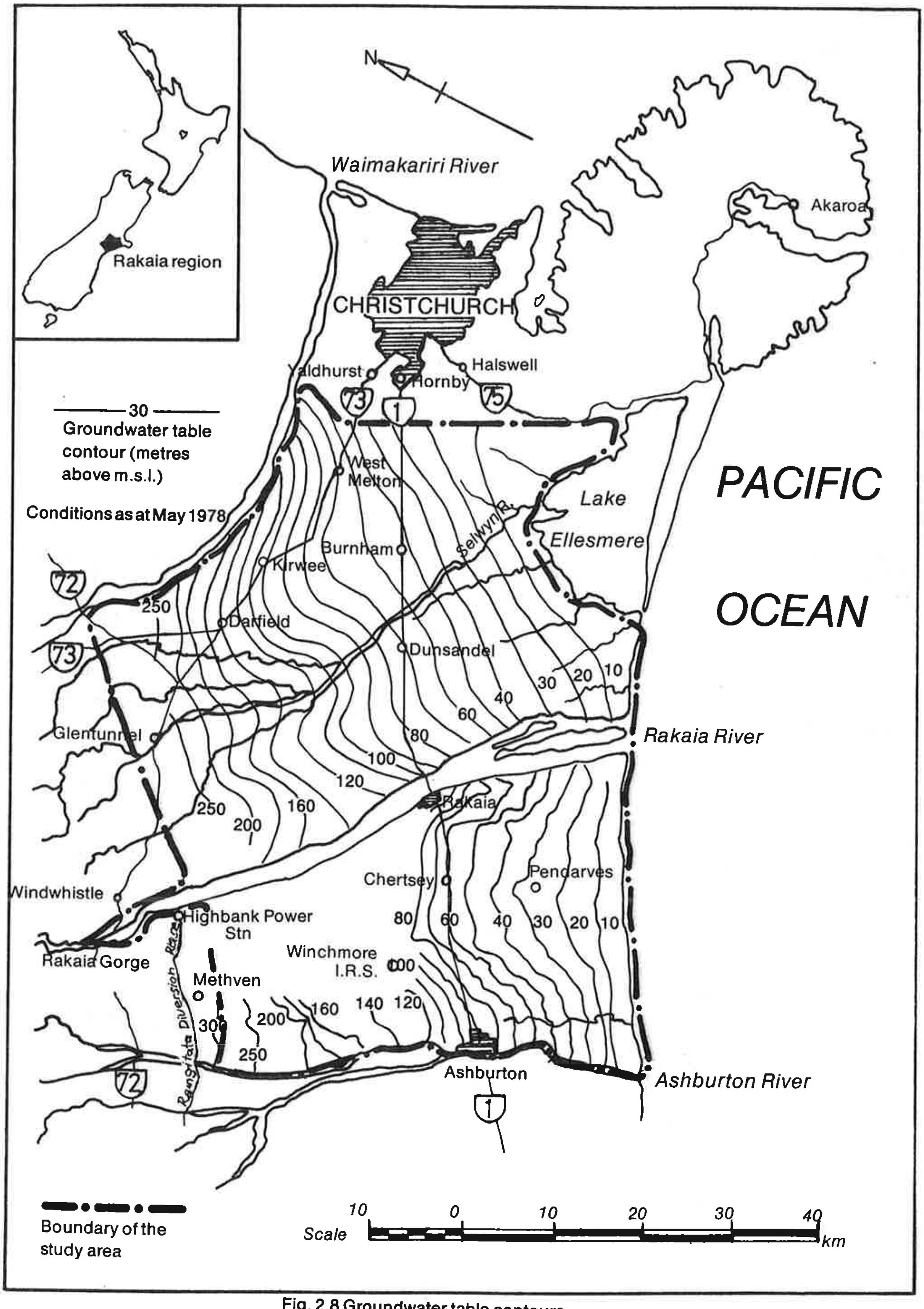


Fig. 2.8 Groundwater table contours
(Sources: Bowden and Thorpe pers. comm.)

Water Quality

Apart from some Imhoff tank effluent at Coleridge Power Station there are no wastes discharged to the Rakaia River. Natural sediment is transported by the river when in fresh or flood. Stephen (1972) listed the constituents of the river water and describes it as a water of high quality.

The quality of the groundwater is now under study and present knowledge suggests that some shallow groundwater may have high nitrate-nitrogen levels due to subsoil drainage from agricultural land. The effect has been reported in the area below the Ashburton-Lyndhurst Irrigation Scheme (Quin and Burden 1979) and in the Lincoln area (Adams, *et al.* 1979). Contamination of groundwater at Templeton and Burnham associated with surface irrigation of treated sewage effluent has also been reported (Martin and Noonan 1977).

2.3 Land Resources

The basement rock in the upper catchment is predominantly greywacke from which glacial outwash gravels and morainic deposits have been derived.

Soils

The soils of the plains are derived from alluvium and loess. The characteristics of the various soil profiles are largely determined by: depth of loess, sand or silt; distribution and coarseness of gravels; age of soil development; and drainage characteristics.

The soils of the area may be classified into several moisture capacity classes. In this study 4 classes were initially used: deep, medium, shallow, and stony. Soils deeper than 45cm and having a sandy loam or silt loam topsoil have been classified either as deep or medium according to DSIR Soil Bureau advice (T. Webb pers. comm.). Also included in the medium group are deep sandy soils, which have lower moisture capacity per unit of depth. Of the rest, shallow or shallow-and-stony soils having sandy loam or silt loam topsoils and reasonable depth of soil are then separated as 'shallow' soils, leaving the remainder as 'stony'. The soils of each group are thus of similar average water holding capacity (Fig 2.9).

Subsequently in the irrigation demand simulations (section 4.1) it was found that there was little difference in demand patterns between the medium and deep soils, and between the shallow and stony soils, so these were aggregated into two groups, A and B (Table 2.3), with water holding capacities under pasture of 85mm and 45mm, respectively.

Soil No.	Soil Group		Soil Depth	Predominant Soil Types
1	Deep	A	0.6–1.2 + m	Barrhill soils; Hatfield, Wakanui and deep Templeton silt loams; Temuka soils.
2	Medium	A	0.45–0.8 m	Templeton, Chertsey and Waimakariri silt loams and fine sandy loams; Paparua, Hatfield and Waimakariri sandy loams.
3	Shallow	B	0.3–0.45 m	Lismore, Chertsey, Eyre, Templeton, Hatfield, Paparua shallow silts and shallow and stony silts.
4	Stony	B	<0.35 m	All stony to extremely stony soils and other shallow and stony soils.

Table 2.3 Soil groups for irrigation demand assessment *(Sources: Ward et al. 1964, Kear et al. 1967, Cox 1978, T. Webb pers. comm.)*

Landscape

In the Rakaia region landscapes can be divided into six different categories:

* the downlands/foothills area;
* the upper plains where mountains are the main backdrop;
* the lower plains where the sea is also visible;
* the lower river reaches with low banks;
* the upper river reaches with high banks and terraces;
* the river Gorge area.

The upper river and Gorge area are most attractive scenically but the middle and lower reaches of the river below the Gorge are rather featureless.

Apart from the major landforms there are many more subtle changes in the character of the landscape which result from changes in soil type and land use, in particular through the choice and arrangement of trees in shelterbelts.

2.4 Biological Resources

From the human viewpoint the main biological resources of the Rakaia region are its fisheries, birds and vegetation readily seen on the land surface. These interact with smaller flora and fauna in a complex ecosystem which is regulated by the rhythm of the seasons.

Fisheries

The fish inhabiting the Rakaia River are described by Davis (1979). She lists the 21 species shown in Table 2.4. Of these, 13 species are migratory, spending part of their life cycle at sea. Four of the species, all of the salmonid family, have been introduced into New Zealand: quinnat salmon, brown trout, rainbow trout and brook char. The rest are native.

Native Species

The native species may be classified according to their location in the river into three categories: estuarine species, lower river residents and others. The important species in each category are now described.

Inanga is the species whose young make up the bulk of the whitebait catch. Inanga spawn in the bank vegetation of estuaries during high autumn tides, the eggs develop in two weeks and hatch on immersion in the next spring tide cycle, and the tiny larvae are washed out to sea. They migrate back to freshwater between August and November as whitebait in the familiar form and mature during the summer

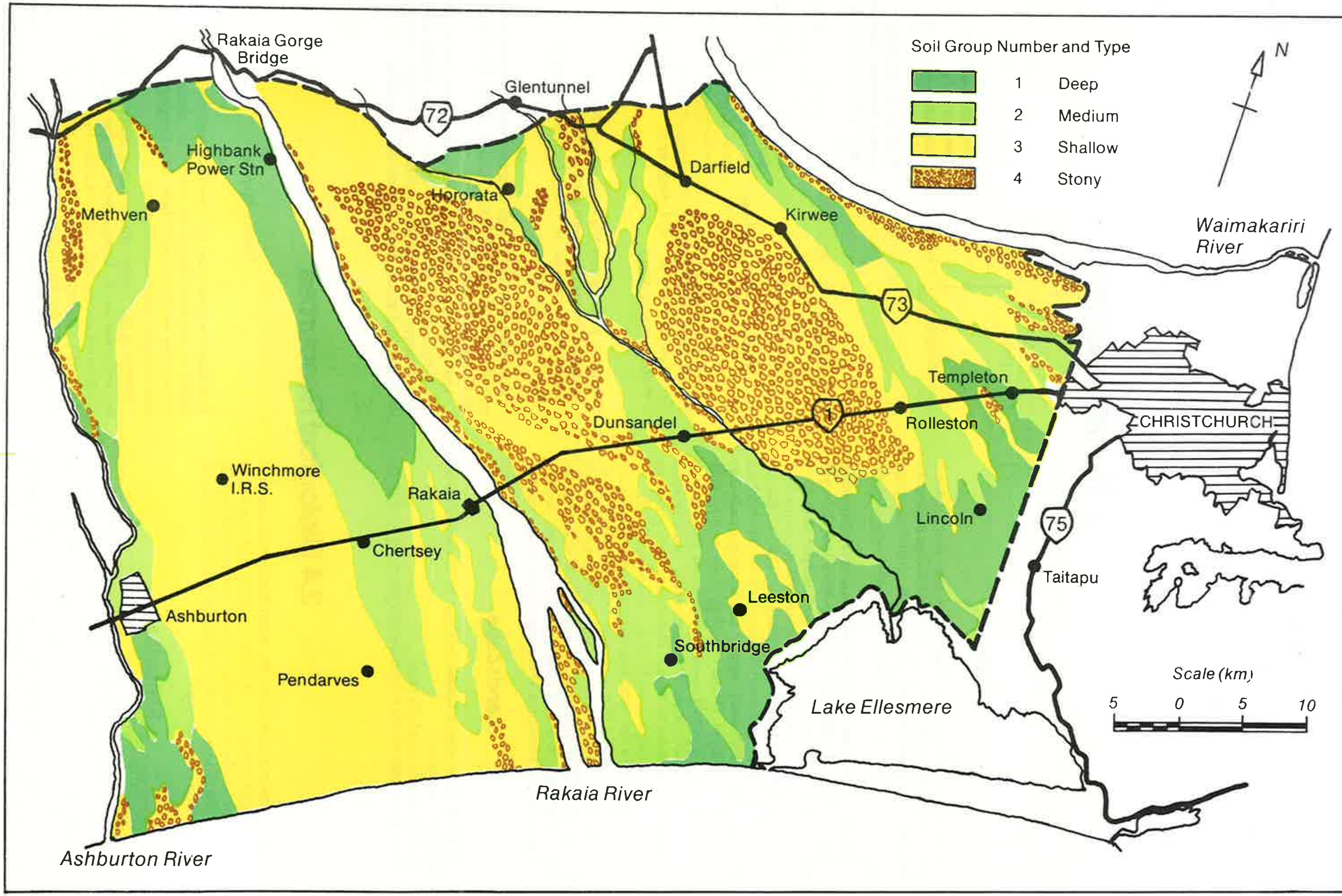


Fig. 2.9 Soils of the Rakaia region

A. *ESTUARINE SPECIES*	
**Galaxias maculatus*	Inanga
Arripis trutta	Kahawai
Aldrichetta forsteri	Yellow-eyed mullet
**Rhombosolea retiaria*	Black flounder
B. *LOWER RIVER RESIDENTS*	
**Retropinna retropinna*	Common smelt
**Stokellia anisodon*	Stokell's smelt
**Gobiomorphus cotidianus*	Common bully
C. *OTHERS*	
**Geotria australis*	Lamprey
**Anguilla dieffenbachii*	Longfinned eel
**Anguilla australis*	Shortfinned eel
**Galaxias brevipinnis*	Koaro
Galaxias vulgaris	Common river galaxias
Galaxias paucispondylus	Alpine galaxias
Galaxias prognathus	Longjawed galaxias
+*Salmo gairdnerii*	Rainbow trout
*+*Salmo trutta*	Brown trout
+*Salvelinus fontinalis*	Brook char
*+*Oncorhynchus tshawytscha*	Quinnat salmon
**Cheimarrichthys fosteri*	Torrentfish
**Gobiomorphus hubbsi*	Bluegilled bully
Gobiomorphus breviceps	Upland bully

Note: * indicates migratory species, + indicates introduced species.

Table 2.4 Fish species inhabiting the Rakaia River
(Source: Davis 1979)

in freshwater ready for their downstream migration to the estuary for spawning in the autumn. Few live longer than one year.

The black flounder is the only New Zealand flat fish which lives in estuaries and enters freshwater; the others are all marine. The black flounder, and the other estuarine species, kahawai and yellow-eyed mullet, are all believed to spawn at sea.

Stokell's smelt, common smelt, and the common bully, are all species whose adults migrate upstream a few kilometres into the lower Rakaia River. Common smelt and Stokell's smelt spawn in or near estuaries, the larvae are washed out to sea, and the adults return when they are one to three years of age. The common bully spawns upstream of the estuary, the larvae spend a few weeks at sea before migrating back to freshwater where they grow to maturity.

The lamprey commences life in freshwater and its larvae take about five years to grow to full size (80–100 mm) before migrating to the sea. They return after about two and a half years to spawn in tributary streams. Lampreys do not feed once they have entered freshwater.

Longfinned and shortfinned eels have the converse life cycle to the lamprey. They breed at sea and their juveniles enter freshwater in a spring migration. Depending on the species, eels take from 9 to 50 years to mature in freshwater before migrating to the sea to spawn and die. Longfinned eels are the most widespread species of fish in New Zealand rivers and streams (McDowall 1978).

Other native migratory species are the koaro (a whitebait species), the torrentfish and the bluegilled bully. All of these species appear to spawn in freshwater and the larvae develop in the sea. The koaro has a spring migration as a juvenile. The torrentfish and the bluegilled bully are the most common native species in the Rakaia River.

Some native species are resident in the Rakaia River throughout their life cycle. These include the common, longjawed, and alpine galaxias, and the upland bully. The galaxias species have a hermitic life style and mostly live in the mountain streams. The upland bully is the most common and widespread bully in the South Island and is present throughout the Rakaia River system.

Introduced Species

Quinnat Salmon

Quinnat salmon from the Sacramento River, California, were first introduced into New Zealand at the Hakataramea hatchery on the Waitaki River in 1901 (Flain 1980). Adult salmon were first observed in the Rakaia River in 1909. The quinnat salmon is the most popular sport fish in the Rakaia River and has been subjected to detailed study. A salmon trap was established on the Glenariffe Stream, a major spawning tributary of the Rakaia, and records of salmon passing to and from the spawning area have been kept from 1965.

The life cycle of the quinnat has four parts: marine residence, upstream migration, spawning, and downstream migration. Little is known of the salmon's marine residence, but when it is two to five years old it enters freshwater, usually homing onto the stream where it hatched. Its upstream migration occurs from December until June with the peak varying from year to year from January to March. The adult salmon ceases eating as soon as it enters freshwater. The journey to the spawning grounds above the Gorge probably takes 1-2 months, but the fish appear to "hole up" in the main river for a month or so to complete maturation of their sexual organs before entering the spawning stream. This may be because the Rakaia is relatively short (140 km) compared with the Sacramento (1200 km).

In the spawning stream, the eggs are laid in a nest made in the gravel bed, called a redd, and are fertilised by the male. The salmon die after spawning. The spawning run at Glenariffe almost always peaks in April with significant numbers also in May. The number of adult fish recorded there varies from 424 in 1973 to 3271 in 1968.

By analysing the scales of returning adult salmon it is possible to determine whether the first year's growth occurred in freshwater or in the sea. Records collected from 1967 to 1976 show that, on average, 40% of returning adults spent all their first year in freshwater, 58% spent part in freshwater and part in the sea, and the remaining 2% spent all of their first year in the sea.

Fluctuation in the numbers of returning adult fish is thought to be related to the incidence of floods during the juvenile rearing period three years earlier.

Trout

Brown trout, originating in Britain, were introduced into New Zealand in 1867 and quickly established themselves in the South Island and southern part of the North Island. They are distributed throughout the Rakaia system. Some brown trout spend much of their life at sea or in an estuary, and migrate upstream to spawn in tributary streams of the Rakaia or in side braids of the main river. However, most brown trout spend all their lives in freshwater. The peak spawning run is in May and June and runs of 200-300 fish are recorded at the Glenariffe trap.

Rainbow trout were introduced into New Zealand from California in 1883. They are not as widespread as brown trout. In the South Island they are usually found in lakes, while in the North Island in rivers. Rainbow trout spawn in tributary streams of the Rakaia River in June and July using smaller redds than salmon. Most adults survive to spawn more than once. They do not migrate to the sea.

Brook char (or brook trout) were introduced from eastern USA in 1877. They are now widespread in Canterbury and Otago, but do not co-exist well with other salmonids and are mostly found upstream from brown and rainbow trout. They also do not migrate to the sea.

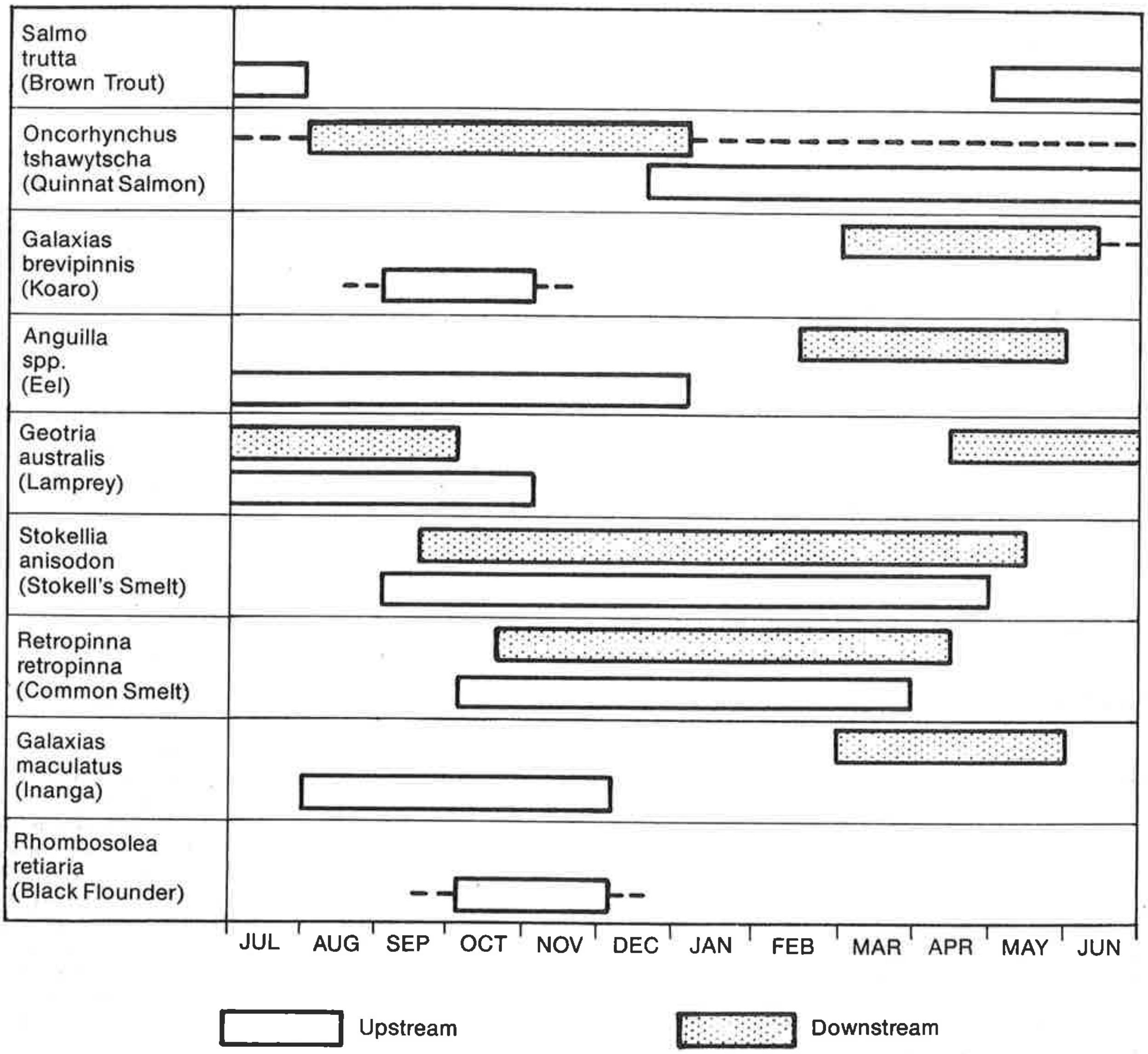


Fig. 2.10 Patterns of migration of fish inhabiting the Rakaia River system
(Source: Davis 1979)

It is apparent from the previous discussion that a major fishery function of the Rakaia River below the Gorge is as a passage and spawning area for species spending part of their life at sea. The timing of these migrations is shown in Fig. 2.10. Migration of one species or another occurs throughout the year.

Many invertebrates (species with no backbone) such as stoneflies, mayflies and caddisflies, live on the river bed. They are the most important food source for fish and birds. In the Rakaia River, invertebrates are most abundant in the riffle areas of minor braids where the bed is more stable. They tend to occupy the margins of a channel rather than the centre.

Birds

The Rakaia River and its environs provide a variety of habitats for 43 bird species known to spend at least part of their life cycle in this region. Of these 43 species, 22 are native to New Zealand. Each individual animal (or indeed plant) inherits a certain range of tolerance for the physical and chemical factors of its environment. The narrower this tolerance the more specialised the organism and the fewer the suitable sites available for its survival.

The broad, open, shingle river bed of the Rakaia and other eastern South Island rivers is the main or exclusive breeding ground for four bird species (Turbott 1969):

Black-billed gull *(Larus bulleri)*
Black-fronted tern *(Chlidonias albostriatus)*
South Island pied oystercatcher *(Haematopus ostralegus finschi)*
Wrybilled plover *(Anarhynchus frontalis)*

The wrybilled plover is the most notable of these species. Its bill is always curved to the right (Fig. 2.11). The bent bill and flexible diet are adapted to its specialised breeding environment. With stable river flows, invertebrate larva are preferred prey and are obtained by direct pecking and by clockwise sweeps beneath the stones of riffles (Pierce 1979). When river levels rise it shifts to the shingle flats where the bent bill is of no particular advantage.

Stead (1932) suggested that the wrybilled plover will nest only on bare shingle beds at least 400 metres wide. Nesting sites are observed from above the Gorge to the mouth of the Rakaia River. The wrybilled plover occupies Canterbury river beds from mid-August to February. It then migrates northwards to its wintering grounds around Auckland where its population has been estimated as 5000 (Sibson 1963).

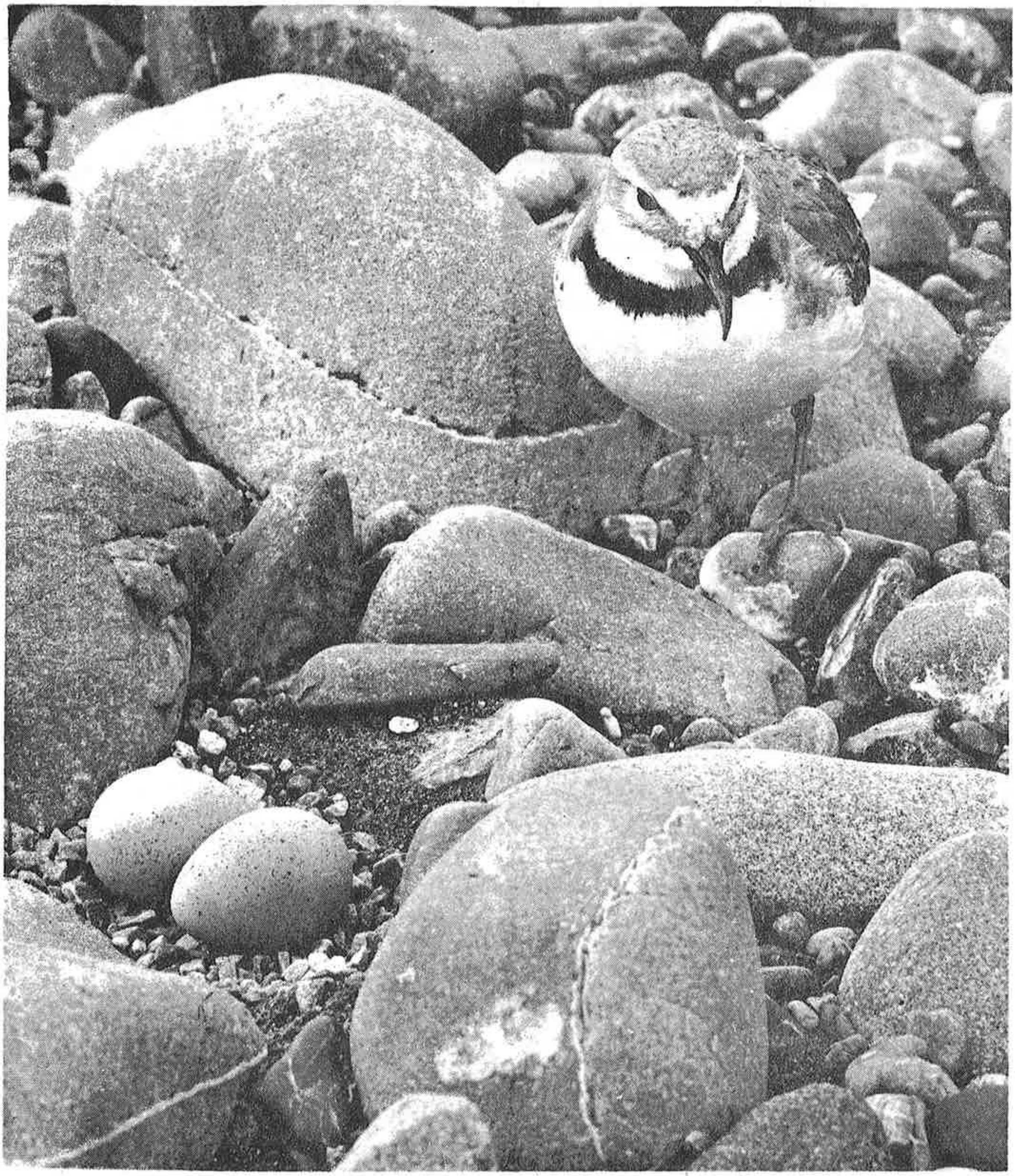


Fig 2.11 The Wrybilled Plover M. F. Soper

The balance of the bird life in the region inhabits the coastline, the open countryside, or inland waters. Inland waters such as coastal lagoons and swamplands having slow moving, shallow water attract game birds including the grey, shoveller, mallard and paradise ducks (*Anas superciliosa, A. rhynchotis, A. platyrhynchos* and *Tadorna variegata*). Open stock water races in the region support significant populations of water fowl.

Flora

The present vegetation of the plains is related to agriculture: pasture species and crops, gorse hedges, and shelter trees which are mainly *Pinus radiata* and eucalypts. Other tree species have been established on the better soils and with careful culture and watering around homesteads. Willows and poplars are common near watercourses. The remnants of native vegetation are mainly tussocks, kanuka, kowhais, coprosmas and cabbage trees.

The river beds have islands of tussocks but these are often invaded or overwhelmed by lupins, gorse and broom. Some river bed swamps have flax and toi toi.

A Scientific Reserve has been established at the top of Great Island in the Rakaia River. This reserve contains a wide variety of native botanical species formerly more common throughout the region.

2.5 Historical and Archaeological Resources

The list of sites classified by the New Zealand Historic Places Trust includes churches, schools, homesteads, various buildings and the Old Rakaia Gorge Bridge (Douglass *et al.* 1979). Their locations are shown in Fig. 2.12.

The known archaeological sites of the region are also shown in Fig. 2.12. These sites comprise ovens, pits, middens, pas, and burial grounds arising from nomadic maori and moahunter occupation. The main concentration of archaeological sites near the Rakaia River is around its mouth. There are very few sites in areas where construction activities associated with irrigation are likely to occur.

2.6 Population Distribution

The population and its distribution in Canterbury is dominated by Christchurch and Ashburton (Table 2.5). In rural areas, small towns provide limited services and labour for the surrounding farming areas. The rural towns were initially developed as service centres for the surrounding hinterland and their location reflects the rail and road transportation network and surrounding land use. Rural population density is greatest in areas to the south of Christchurch where soils are deep and there are many dairying and small farms (Fig. 2.13). Although Table 2.5 shows a drop in the population of Methven from 1971 to 1976, the development of the Mt Hutt skifield has stimulated commercial activity there and it is expected that the population of Methven will have increased by the next census.

'Rural/urban' drift has been a feature of New Zealand's population for many years. From 1961 to 1971 the rural area of the Canterbury region had a nett loss of 20% of its 1961 population (Canterbury Regional Planning Authority 1977).

	1971	1976
Christchurch	275,968	295,296
Ashburton	13,312	14,225
Malvern County		
Darfield	829	1,561
Kirwee	188	213
Coalgate	213	219
Glenroy	162	152
Glentunnel	140	156
Hororata	267	252
Sheffield	217	219
Waddington	136	149
Springfield	310	326
Ashburton County		
Rakaia	780	759
Wakanui	138	143
Chertsey	216	222
Methven	1,025	918
Ellesmere County		
Doyleston	263	264
Dunsandel	365	365
Leeston	784	866
Lincoln	1,387	1,604
Rolleston	578	801
Southbridge	487	506
Springston	348	368

Table 2.5 Population of towns and rural settlements
(Source: Douglass et al. 1979)

Decreasing rural population has caused some of the services and functions of the small towns to become uneconomic. Many of these functions have, consequently, been lost and centralised in the larger towns.

In the Lower Rakaia area, the rural losses have not been as great as in the Central Plains and foothills. Irrigation proposals in both areas will allow modest but significant population gains. In the Central Plains area, irrigation will reverse a falling population trend and make better use of the social and community resources of the near foothill settlements. (Douglass *et al.* 1979).

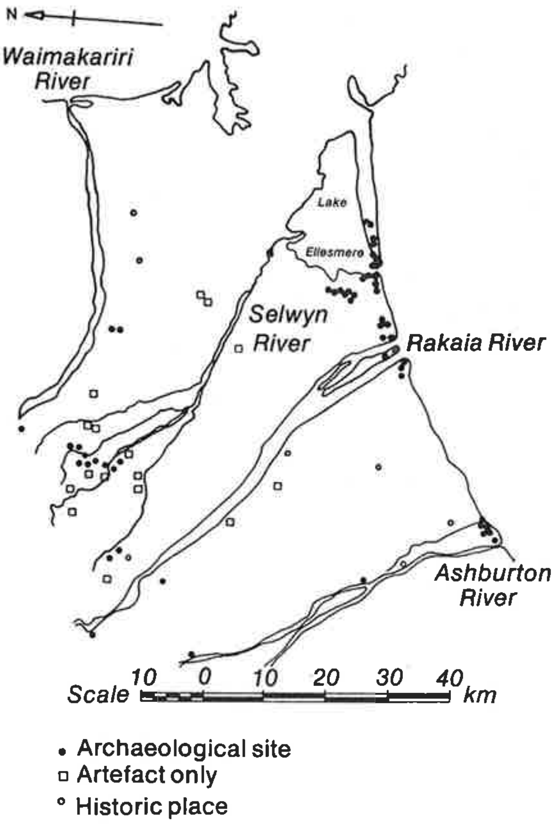


Fig. 2.12 Archaeological and historic sites of the Rakaia region
(Source: Douglass et al. 1979)

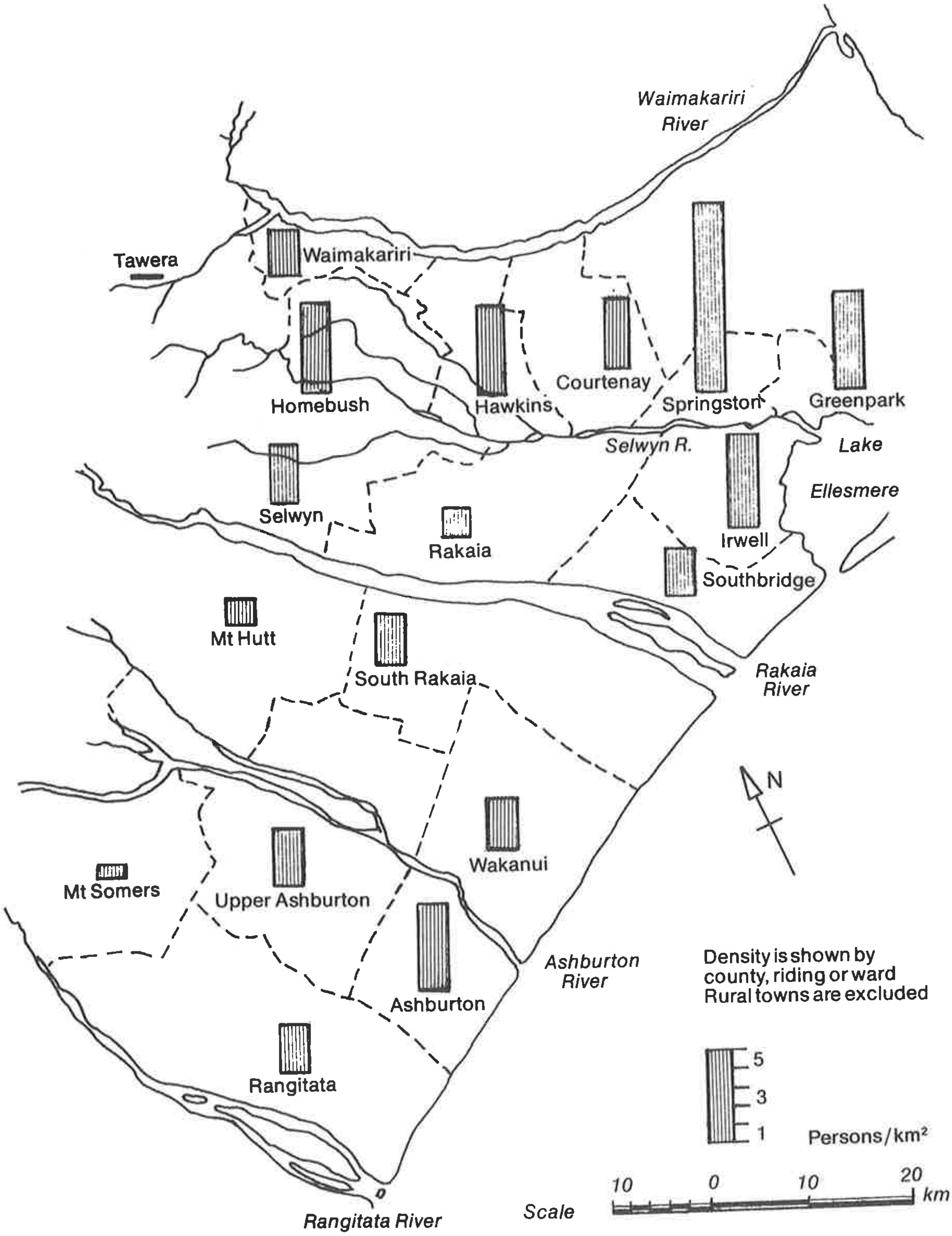


Fig. 2.13 Rural population densities in the Rakaia region, 1976.
(Source: Douglass et al. 1979)

3 Water Use

3.1 Irrigation

The purpose of this section is to assess for the Rakaia region the area now being irrigated from river diversions and from groundwater, the quantities of water being used, and the rates at which development has taken place.

Data on irrigated area and irrigation water use are summarised in Table 3.1 The trend has been for community schemes using river water to irrigate by surface flooding (mainly border-dyke) and for individual farmers using groundwater to spray irrigate.

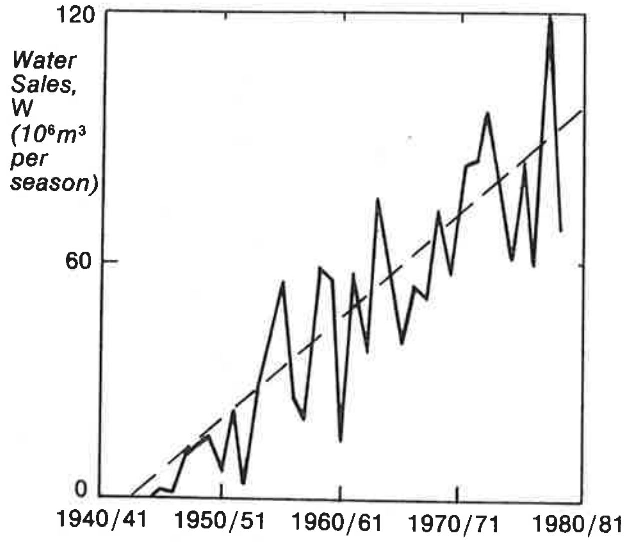
Irrigation Using River Water

The construction of community schemes for irrigation was initiated in Canterbury in the 1930's. Within the study area three community schemes are currently in operation: Ashburton-Lyndhurst, North Rakaia and South Rakaia. Scheme locations are shown in Fig. 4.1. The Ashburton-Lyndhurst scheme draws its water from the Rangitata Diversion Race, while the North and South Rakaia schemes draw theirs from the Rakaia River. Less than 0.5% of the mean annual flow of the Rakaia River is currently abstracted for irrigation.

	Irrigated Area (ha)	Volume Water Abstraction (10^6 m^3/yr)	Average Rate Water Abstraction (m^3/s)
Community schemes			
Ashburton-Lyndhurst	11,850	155	7.3
North and South Rakaia	1,600	20	1.0
Individual farms			
South of Rakaia R.	9,600	30	2.8
North of Rakaia R.	12,200	44	4.3
Total	35,250	249	15.4

Notes: (1) Community irrigation schemes use river water mainly for border-dyke irrigation. The Rangitata River supplies the Ashburton-Lyndhurst scheme, and the Rakaia River the North and South Rakaia schemes.
(2) Individual farms mostly use groundwater for spray irrigation. Data shown are the areas and abstractions nominated on their water rights.
(3) Average rate of abstraction is over the irrigation season 1 Sept. to 30 April.

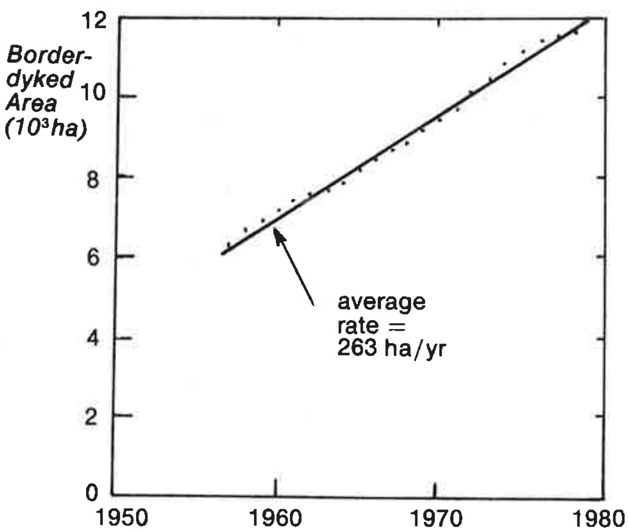
Table 3.1 Summary of present irrigation water use in the Rakaia region



--- Regression line equation is
$W = 2.62t + 1.35$ ($r = 0.868$),
where 1944/45 is $t = 1$
and 1978/79 is $t = 35$.

Fig. 3.1 Water sales on the Ashburton–Lyndhurst irrigation scheme, 1944–79

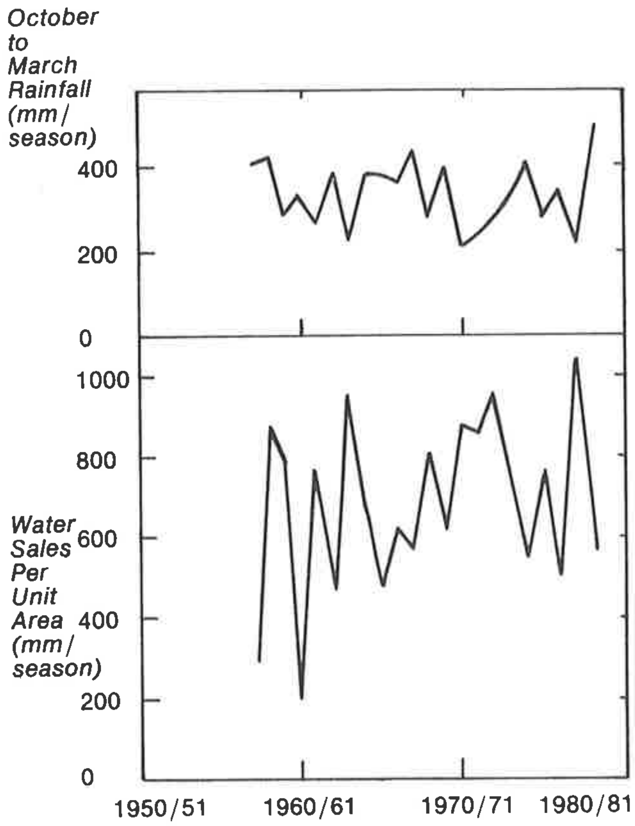
Note: Figs 3.1 and 3.3 — data are for irrigation season 1 September–30 April



(Border-dyke area prepared by MWD; does not include private development)

Fig. 3.2 Development of border-dyked land on the Ashburton-Lyndhurst irrigation scheme

The development over time of irrigation water use in the Ashburton-Lyndhurst scheme is shown in Fig. 3.1. This demonstrates that, allowing for climatic variations, water delivered to the farms has been growing linearly from 1945 to 1979 at a rate of 2.6×10^6 m^3/yr. This suggests that the irrigated area has been growing linearly also, and for the period 1957 to 1979 this is confirmed by Fig. 3.2 which shows that the border-dyked area developed by Government construction has been increasing at a constant rate of 263 ha/year, a little over 1%/year of the gross area commanded by the scheme. These figures do not include private development of border-dyked land estimated as being 10% of construction by Government forces.



	Mean (mm)	Coefficient of variation (%)
Oct–Mar rainfall	339	23
Water sales	687	31

Fig. 3.3 Rainfall and water sales per unit area on the Ashburton–Lyndhurst irrigation scheme

Dividing the volume of water delivered to the farms by irrigated area, the equivalent depth of water delivered can be estimated. For the Ashburton-Lyndhurst scheme, this averages 687 mm/season for the period 1957 to 1979, Fig. 3.3. The variability in water use from year to year due to climatic variation has a range of from 30% to 150% of this average figure, and is inversely related to rainfall in the irrigation season.

Irrigation Using Groundwater

Irrigation from groundwater in the Rakaia region has been developing rapidly since 1970 using mainly modern low-labour spray application techniques. The demand is greatest near the coast and near the major rivers where groundwater is closer to the surface. Demand diminishes going inland where groundwater must be pumped from more than 40 m depth.

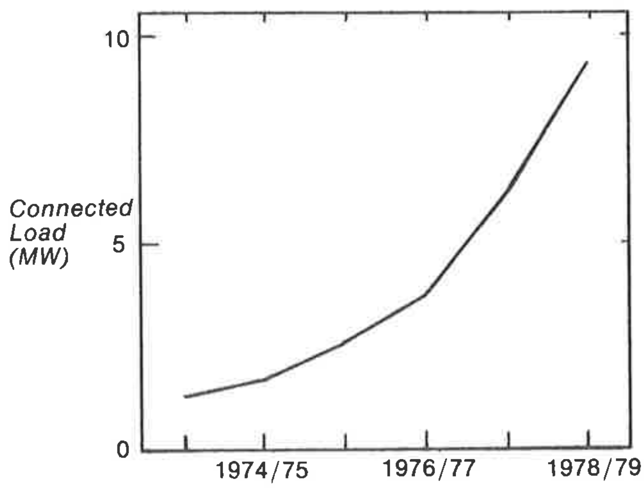
(a) South of the Rakaia River

A survey of spray irrigators in a 43,100 ha area within the proposed Lower Rakaia irrigation scheme (Lord 1979) found that 7940 ha of this land is currently irrigated by spraying on 54 farms with an average irrigated area of 146 ha per farm. A further seven irrigators outside this area were surveyed who are irrigating 1290 ha. Allowing for omitted irrigators, these figures suggest that between the Rakaia and Ashburton Rivers at least 10,000 ha are currently irrigated from groundwater.

As of September 1979, the South Canterbury Catchment Board have granted 101 water rights for irrigation between the Rakaia and Ashburton Rivers (Stringer pers. comm.). More than 90% of these utilise groundwater. The total irrigation area nominated in the rights is 9573 ha with an average daily flow of 2.93 m^3/s over the irrigation season.

Lord estimated that the average flow of the 69 wells surveyed was 41 l/s, or 0.28 $l/s.ha$ irrigated. All water was being pumped from a depth of 70m or less, with half the wells having a pumping level of less than 30m. Applying a unit demand rate found by his survey of 0.28 $l/s.ha$ to 10,000 ha gives an average withdrawal rate from groundwater in the Lower Rakaia area of 2.8 m^3/s during the irrigation season for the Lower Rakaia area as a whole. This estimate agrees well with the flow nominated from the water rights.

The Ashburton Electric Power Board has a special "T" rate which is used for spray irrigation and some grain drying. It is estimated that 120 of the Board's 210 "T" rate subscribers live in the area between the Ashburton and Rakaia Rivers. The growth over time of spray irrigation in the Lower Rakaia area is related to the connected electrical generating load for pumping, shown for "T" rate in Fig. 3.4. Connected load has been increasing at an average rate of nearly 50% annually from 1973 to 1978.



Data are for financial year March to March

Fig. 3.4 Electrical generating load on "T" rate in the Ashburton–Rakaia area
(Source: Ashburton Electric Power Board pers. comm.)

(b) North of the Rakaia River

The extent of spray irrigation between the Rakaia and Waimakariri Rivers can be assessed from data on water rights, compiled by the North Canterbury Catchment Board (Hamilton pers. comm.). Since 1972 new water rights were granted in the study area for a total of 12,200 ha with an average irrigated area of 44 ha per water right. The rights are for withdrawal for 120 days and the average allowable withdrawal is 0.35 $l/s.ha$ (maximum allowable withdrawal is 0.48 $l/s.ha$). Total allowable withdrawal is therefore $44 \times 10^6 m^3$ in 120 days or 4.3m^3/s average flow over this period. As these data are for water rights rather than actual withdrawals they are likely to represent an upper limit on spray irrigation water use in this area.

By comparing the estimated withdrawal rates from groundwater with the estimates of groundwater recharge (Table 2.2) it can be seen that on average only 3-12% of total groundwater recharge is being withdrawn within the Rakaia region. This suggests that groundwater resources could be much more fully utilised than they are at present.

3.2 Fishing

Fishing is the major recreational activity in the Rakaia River. The river forms the boundary between the North Canterbury and Ashburton acclimatisation societies, who together issued 18,600 annual fishing licences in 1977-78, 15,460 by the North Canterbury society and 3,140 by the Ashburton society. Additionally, during 1978, the two societies issued 2,600 daily or weekly fishing licences. It may be concluded that there is a total of around 20,000 licences issued annually for fishing in north and central Canterbury.

The Ministry of Agriculture and Fisheries and the Acclimatisation Societies have undertaken a number of investigations to assess the angling pressure on the lakes and rivers in the region. The main investigations pertinent to this study are: a salmon creel census of the Rakaia (Boud and Cunningham 1957); the national angling diary scheme run every five years from 1952 to 1967 (Graynoth 1972); a postal questionnaire run in the North Canterbury Acclimatisation District in 1958 and 1963 (Graynoth 1972); a combined diary and creel census survey of the Rakaia River attempted in the 1973/74 and 1974/75 seasons (West and Goode 1980); and a postal questionnaire of anglers in the North Canterbury Acclimatisation District carried out in 1976 by Octa Associates on behalf of the North Canterbury Acclimatisation Society, which received 1285 replies out of the 2000 licence holders surveyed (Octa Associates 1976).

The Octa survey found that the most popular fishing area for residents of the North Canterbury Acclimatisation District is the Waimakariri River downstream of the Gorge Road Bridge, where 51.7% of the survey respondents fished at least once in a season. The Rakaia River was rated second in importance with 38.8% of the respondents using it at least once. As the North Canterbury Acclimatisation Society covered by the Octa survey has a much larger membership than the Ashburton Society, it may be estimated that the number of people who occasionally go fishing on the Rakaia River is approximately 40% of the total number of local licence holders, or about 8,000 people.

The Octa survey concluded that the Waimakariri River downstream of the Gorge Road Bridge, and the Rakaia River are the most popular areas for North Canterbury Acclimatisation Society members fishing for sea-run salmon.

Graynoth and Skrzynski (1974) reported that the Selwyn River is the best trout fishery in the North Canterbury Acclimatisation District as it closely approaches an ideal river with many large fish to be caught. However, the Octa survey showed that the Waimakariri (downstream of the Gorge Bridge), Lake Ellesmere, Lake Coleridge and the Ashley are more popular than the Selwyn for trout fishing. The Rakaia is not a highly rated trout fishery. Most anglers go to the Rakaia to catch salmon and the Rakaia's trout stocks are under-utilised.

Flounder, whitebait, eels and kahawai are other species caught in the study area. When the salmon are not running fishermen tend to pursue other types of fishing e.g. whitebaiting, setting nets for flounder, surfcasting for kahawai, or fishing for sea-run brown trout.

The Ashburton River is also used by whitebaiters but the Selwyn River is not very accessible to whitebait as Lake Ellesmere is usually closed to the sea.

Overall growth in the fishing community can be assessed from the growth of angling licence sales, shown in Fig. 3.5 for the North Canterbury Acclimatisation District. Total sales have been increasing at an average rate of 330 licences per year, equivalent to 2% of the total licence sales in the 1977/78 period, mainly caused by increases in the sales of men's licences rather than women's or junior licences.

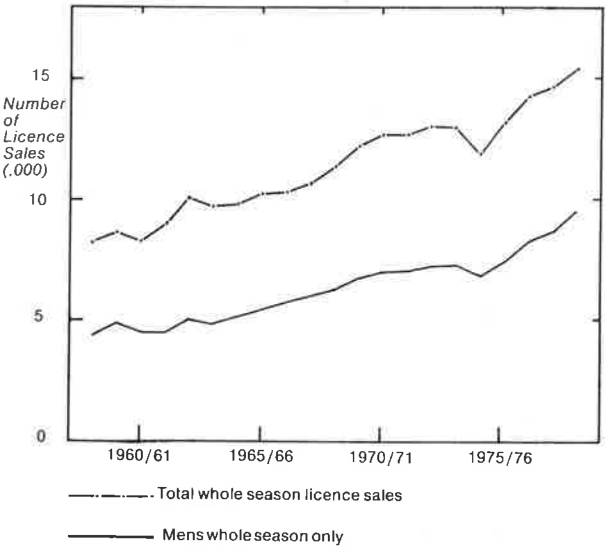


Fig. 3.5 Angling licence sales in the North Canterbury Acclimatisation District, 1958–78
(Source: North Canterbury Acclimatisation Society pers. comm.)

As at August 1979, two commercial salmon farming operations had been proposed for the Rakaia River. From one farm, being constructed near the Lake Coleridge Power Station tailrace, it is planned to release 1 million fingerlings in early 1980. From 1-5% of these are expected to return as adults. During 1979 a boat was purchased for commercial kahawai fishing at the mouth of the Rakaia. In 1978/79 three eel fishermen operated on the Rakaia River, catching approximately 15 tonnes of eels (0.75% of the total New Zealand eel catch).

3.3 Other Recreation

Besides fishing, significant recreational use of the Rakaia River is made for jet boating, canoeing, picnicking and swimming.

Jet Boating

The Rakaia River is frequently used by jet boaters. One of its greatest attractions is that it is one of the few large rivers which are navigable from the mouth to the headwater streams. Although it is the only suitable jet boating resource within the study area, regionally it is not unique. All the major rivers of the South Island's east coast are suitable for jet boating, but most are blocked by barriers, natural or man-made. The Rangitata River offers braided waters and, in its gorge, extremely difficult rapids which are impassable except to the most experienced jet boater. The Waimakariri River is the most popular jet boating river in Canterbury, largely because of its proximity to Christchurch.

During 1979, the consulting firm of Gabites, Alington and Edmondson made a postal survey of the Canterbury branch of the New Zealand Jet Boat Association (Douglass *et al.* 1979). As of April 1979, this branch had 534 members, most of whom own jet boats and covers all the area from North Canterbury to Ashburton and Geraldine. Approximately 10% of the members responded to the survey. The replies demonstrate that the whole length of the Rakaia River is used for jet boating with the areas below State Highway 1 bridge and above the Gorge bridge being slightly more popular than that between the bridges. Of activities associated with jet boating, salmon fishing is by far the most popular. Two thirds of those who answered combined salmon fishing with their jet boating trip. Family picnics were the second most popular associated activity.

Membership in the Canterbury branch of the New Zealand Jet Boat Association increased during 1970–76, but has been static since that time.

Canoeing

Canoeists travel extensively to gain different canoeing experiences. Popular rivers in Canterbury for canoeists are the Rangitata for its fast and exciting water, the Hurunui for its variety, and the Waiau for its accessibility. Egarr and Egarr (1978) reported that the Rangitata River from the Rangitata Diversion Race intake at Klondyke to Peel Forest is the most popular river trip, followed by the Hurunui above Maori Gully.

Use of the Rakaia River is concentrated in the Gorge and some trips extend a few kilometres in the braided section down to Highbank. This Gorge trip is recommended for beginning canoeists; there are no difficult rapids and the greatest hazard is wind.

There are several local canoe clubs although many canoeists do not belong to a club. The largest is the University Canoe Club with 200 members and membership growing at the rate of 10 per year. These clubs have collected records of visits made by their members to various rivers. As shown in Fig. 3.6 these data show that the Rakaia River has very little attraction as a canoeing river compared with others in the region. The data given in this figure do not cover all canoe visits to these rivers but they are considered to reasonably reflect the relative popularity of the various rivers.

Swimming and Picnicking

Within the study region popular swimming and picnic areas occur at Whitecliffs, Coes Ford on the Selwyn River, and Glentunnel Domain. These areas are used more than the

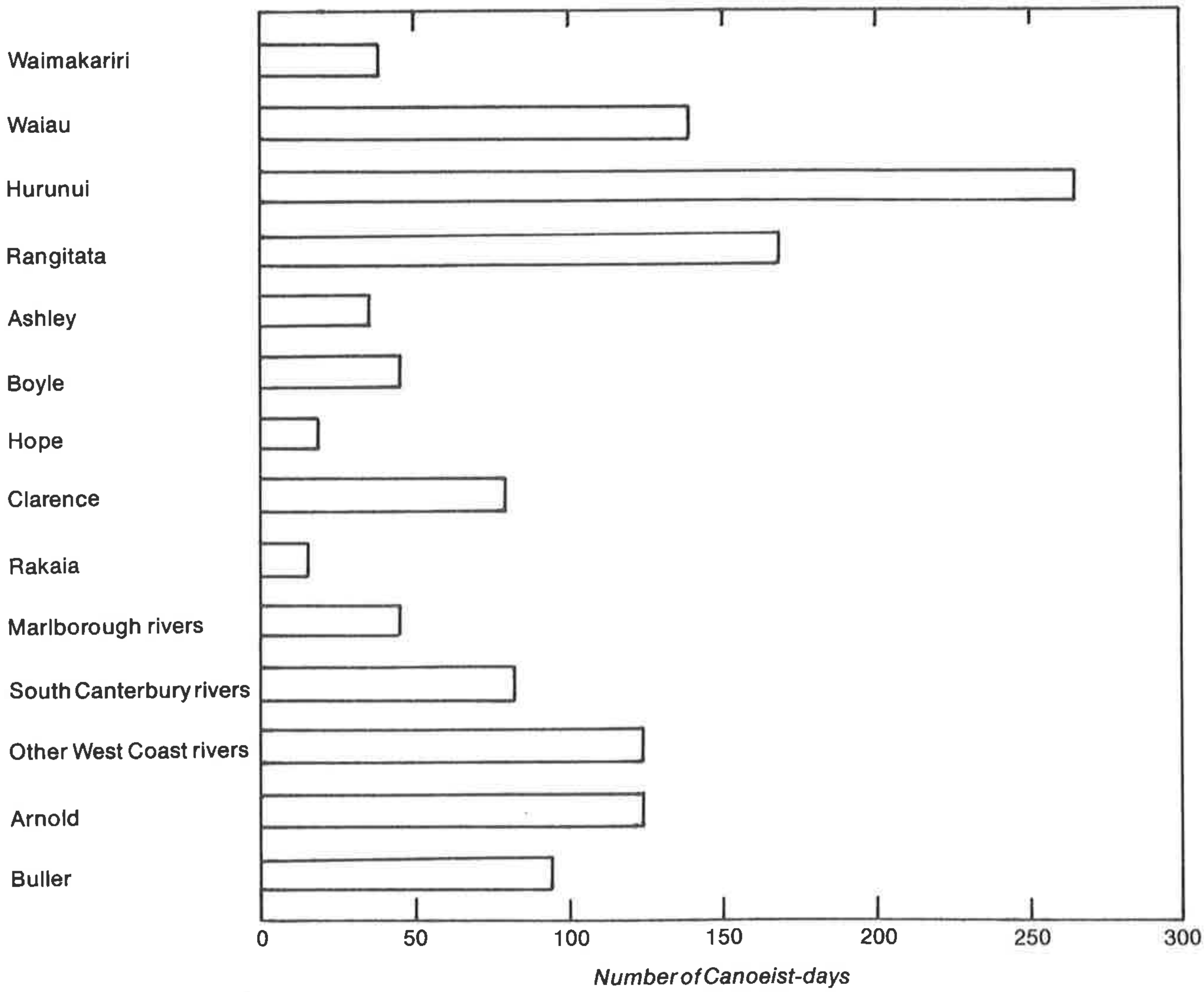


Fig. 3.6 River usage by Christchurch canoeists, Sept 1978–May 1979
(Source: Combined Christchurch Canoe Clubs 1979)

Rakaia River itself.

Ayrey (1971) located four areas on the Rakaia used regularly for bathing: the lagoon behind the Rakaia Huts fishing settlement on the north bank, behind the bridge to Great Island farm (known as Dobbins Ford), at Rakaia township, and Lake Heron.

The area behind the Gorge Bridge is also used occasionally by swimmers but the water is turbulent and cold. At other points, the river is used occasionally for swimming in conjunction with a family picnic, fishing, or a jet boating trip. In general the mainstreams of the Rakaia are erratic and turbulent and have unknown or hazardous features which discourage swimming. The water is cold and there are few holes or sidestreams suitable for swimming.

The lower Rakaia River is not particularly attractive for picnickers mainly because of its lack of shelter and difficulty of access to water for family groups. Picnics are normally combined with jet boat or fishing trips.

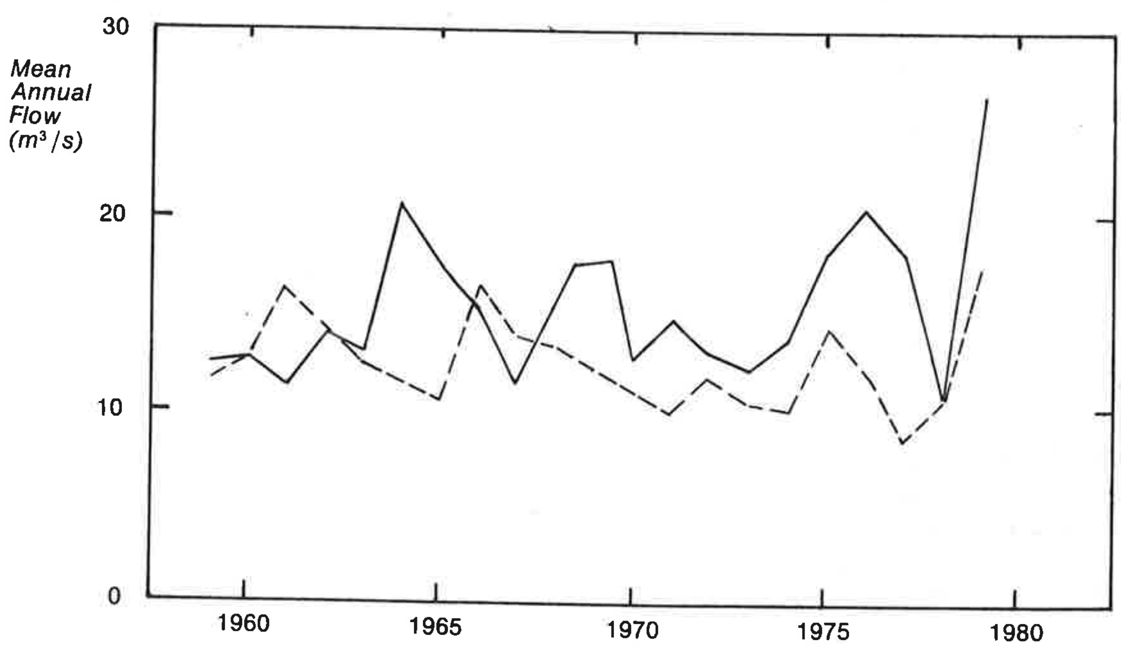
3.4 Hydro-electric Power

Two power stations discharge water into the Rakaia River. The Lake Coleridge Station located above the Rakaia Gorge has an installed generating capacity of 35 MW and produced 137 GWh/year of energy on average for the period 1958–78. The Highbank Station located at the end of the Rangitata Diversion Race below the Rakaia Gorge receives most of its water from the Rangitata River. Highbank has an installed capacity of 25 MW and generated 89 GWh/year of energy on average for the 1958–78 period.

Water use for power production did not vary greatly from year to year from 1958–78, as shown in Fig. 3.7, and the mean annual flows through the two stations were 15.6 m^3/s at Lake Coleridge and 12.5 m^3/s at Highbank for this period. Power production in a given year is significantly affected by the extent of stoppages for machine maintenance and the annual flows through the Highbank and Coleridge stations were not significantly correlated with each other.

Power generation can affect daily flows in the Rakaia River particularly during low flow periods. From June to August power generation is at its maximum for the year with combined outflows from both stations of the order of 50 m^3/s, compared with an average Rakaia River flow for those months measured at the Gorge station of 140 m^3/s. For the summer period from December through February the combined outflow from the power stations has averaged 15 m^3/s compared with a mean flow of 225 m^3/s at the gorge for those months.

In the past the effect of storage of diverted river water in Lake Coleridge has been to retain flood flows for discharge in the winter using Coleridge as a peak load station. With the completion of the Wilberforce Diversion in December 1977, the availability of diverted water for power has increased from an average of 11 m^3/s to about 20 m^3/s (Ibbitt 1979) and Coleridge now operates more as a base load station with little fluctuation in water level in the lake. Peak diversions into Lake Coleridge can be more than 50 m^3/s.



Data are for the financial year ending in March of the year stated

Fig. 3.7 Water use for power production at Highbank and Lake Coleridge, 1959–79 *(Source: New Zealand Electricity pers. comm.)*

3.5 Rural Water Supply

Rural water supply schemes to the north and south of the Rakaia River draw water from the river. To the north the Ellesmere County Council operates two intakes with a combined flow of 1.8 m^3/s supplying 46,500 ha; to the south the Ashburton County Council operates the Acton-Main drawing 0.6 m^3/s to supply 23,500 ha. These are open stockwater races constructed around 1900. Proposals to pipe these supplies are being mooted and when these are carried out water use will be reduced by at least 80%.

Rural water supply is also delivered to 15,200 ha in Malvern County to the north of the Rakaia, but this is not drawn from the Rakaia River.

4 Planning for Irrigation Development

4.1 Potential Irrigation Water Use

In the official programme of irrigation developments adopted by the National Water and Soil Conservation Authority in 1974-75 the next community schemes to be undertaken in Canterbury are the Lower Rakaia scheme (64,000 ha) and the Central Plains scheme (128,000 ha) as shown in Fig. 4.1. Both schemes would involve the combined use of surface water from the Rakaia River and groundwater pumped from the underlying aquifers.

These are the largest community irrigation developments proposed in New Zealand and they would involve substantial diversion of surface water from the Rakaia River, with a flow to the Lower Rakaia area comparable to that in the present Rangitata Diversion Race ($31 m^3/s$), and about twice that flow going to the Central Plains area. Should these schemes proceed, the capital expenditure involved and the impact on the water resources of the region justify careful advance study to estimate the amount and time distribution of the demands for irrigation water. This section describes the calculation of these water demands.

Method

All methods for estimating this demand involve summing the water requirements of unit areas of soil-crop combinations. The basic equation used is:

$$Q(t) = \frac{1}{E} \sum_{j=1}^{J} \sum_{k=1}^{K} A_{j,k} I_{j,k}(t) \qquad \ldots(4.1)$$

where $Q(t)$ = daily average irrigation demand rate (m^3/s)
E = irrigation efficiency
$A_{j,k}$ = area (ha) of crop j grown in subregion k; $j = 1,2 \ldots J$; $k = 1,2 \ldots K$. The different subregions can correspond to different soil types.
$I_{j,k}(t)$ = daily average unit crop water demand of crop j on subregion k ($m^3/s.ha$)
t = time index (days); $t = 1,2 \ldots T$.

Previous studies of irrigation demands in Canterbury have used this equation in various forms (Bowden 1974, Taylor 1974, Southern Energy Group 1976, Smart 1978).

Smart (1978) developed a soil moisture accounting model which may be used to assess $I_{j,k}(t)$. Based on work at Winchmore Irrigation Research Station (Rickard and Fitzgerald 1973) this model simulates moisture deficits in the soil using daily time steps and records of rainfall and pan evaporation from 1967-73, with irrigation applied according to a predetermined strategy. The present work builds on that of Smart.

The different soil types are combined into two groups with water holding capacity under pasture of 85 and 45 mm (section 2.3). The crops are differentiated into seven types: pasture, lucerne, winter cereals, spring cereals, small seeds, peas and fodder beet.

Water can be applied to the soil by two strategies: "rostered" or "on demand". Rostered irrigation, as used for border-dyke irrigation in community schemes, allows the water to be applied only at specified intervals of time. On demand irrigation allows the water to be applied whenever it is needed. In the present study pasture and lucerne are irrigated on a roster cycle, and cereal and seed crops on demand.

Two sets of climatic data (rainfall and evaporation) were

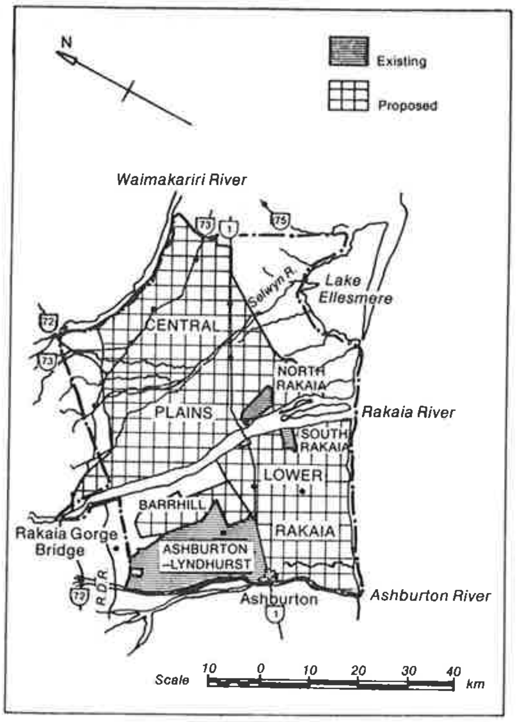


Fig. 4.1 Existing and proposed community irrigation schemes in the Rakaia region

used: Winchmore data for the Lower Rakaia area and Darfield data for the Central Plains area. Daily simulations from August to April were made for each of the soil-crop combinations over 11 seasons, 1967/68 to 1977/78. At each climate station the annual rainfalls for the 11-year study period were checked against the long-term annual rainfall series and found to be statistically similar, so this study period is considered to adequately represent the long-term rainfall conditions in the area.

There is a rainfall gradient from the hills to the coast (Fig. 2.3) but tests made using different rainfall and evaporation records in the soil moisture simulations showed that the small differences in the water demands produced were not significant when compared with the variations from other factors used in the analysis.

Results

Irrigation water demand simulations were carried out for all scheme options considered. To show the type of results produced those of a particular option (LR 3/23 in section 4.2) are described. In this option 39,000 ha in the Lower Rakaia area would be irrigated using water from the Rakaia River. The crop distribution adopted is 77% in pasture and lucerne, 23% in cereal and seed crops. A 23-day roster cycle is used for the pasture and lucerne.

Fig. 4.2 shows the simulated water demands from this area for 1977/78 (dry season) and the average demand curve over all 11 seasons examined. The variation between these demand profiles results mainly from the variation in rainfall over the irrigation seasons. The average demand profile

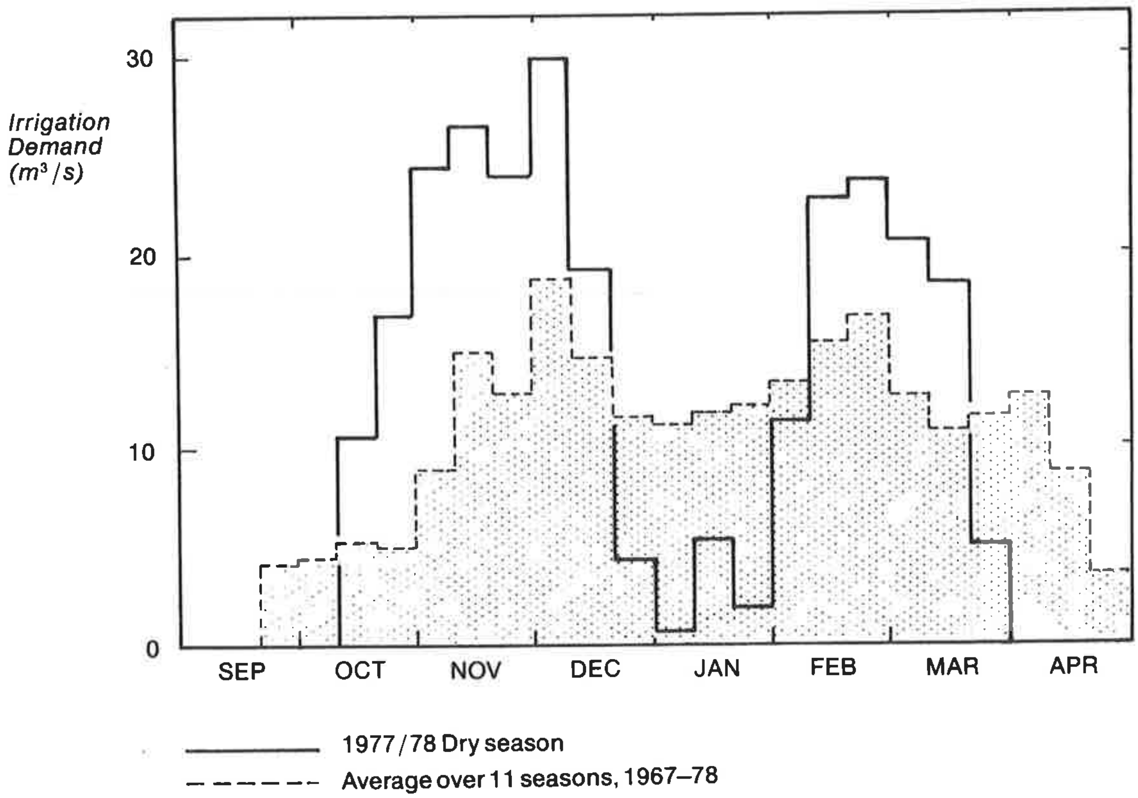


Fig. 4.2 Irrigation water demands for average and dry seasons

Note: Figs 4.2 and 4.3 are based on Lower Rakaia River Supply Scheme 3, 23 day roster (LR 3/23).

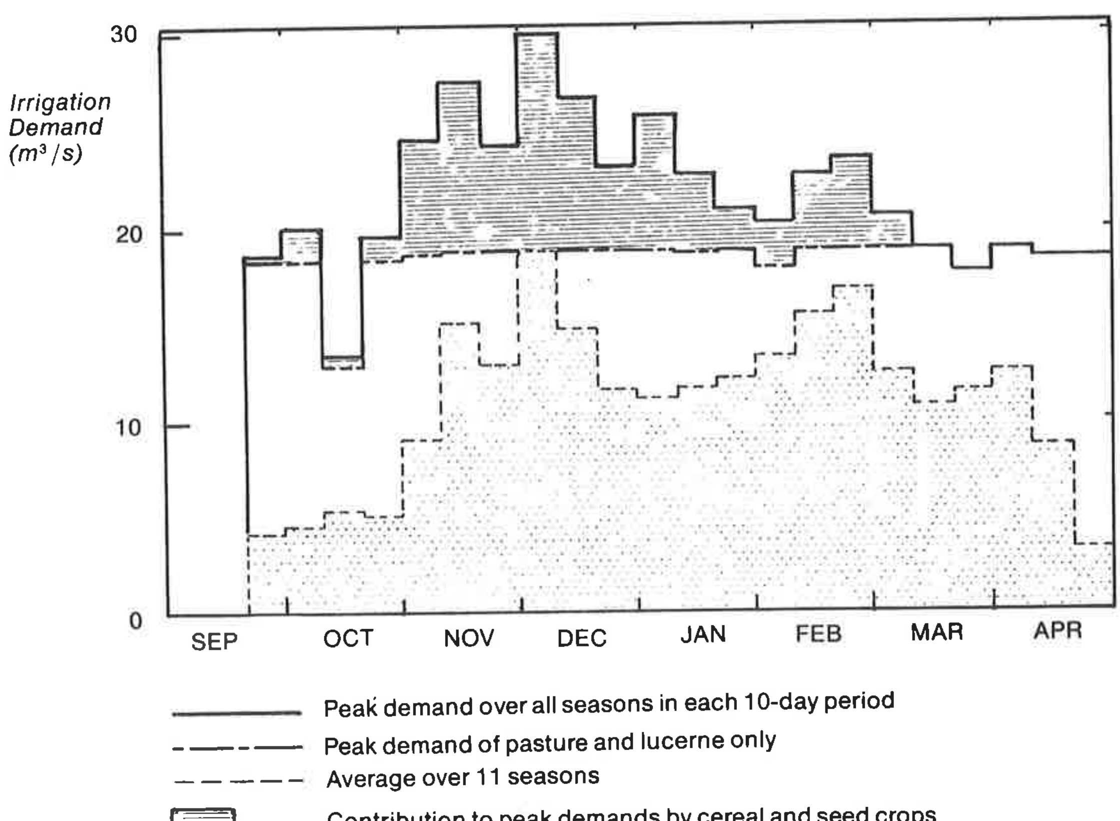


Fig. 4.3 Peak and average irrigation water demands

ALTERNATIVE SUPPLY SCHEMES

Scheme Designation	Component Segments	
	River Supply	Groundwater Supply
LR 1	2–7	1
LR 2	3–7	1,2
LR 3	4–7	1–3
LR 4	5–7	1–4
LR 5	6,7	1–5
LR 6	7	1–6

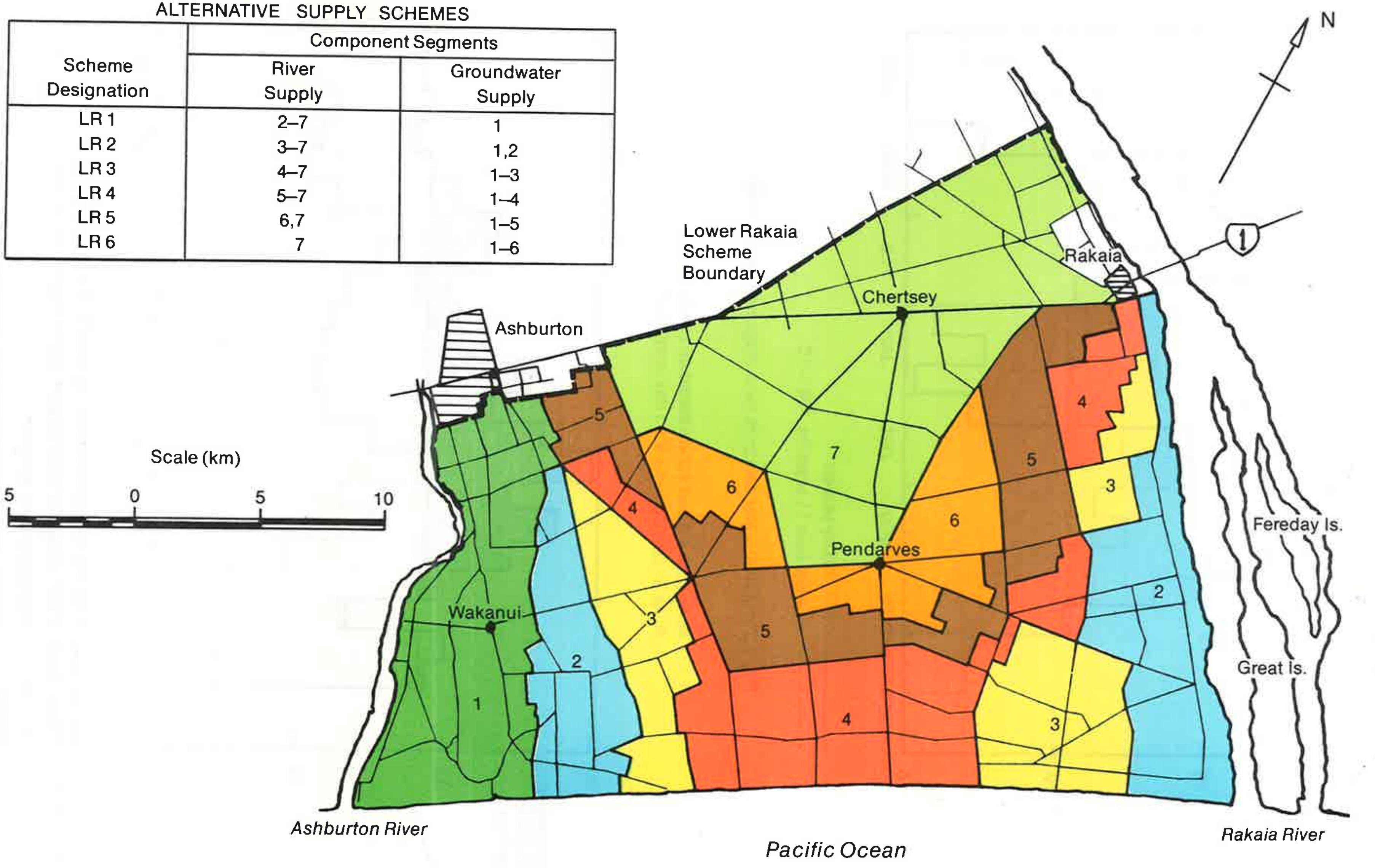


Fig. 4.4 Lower Rakaia groundwater segments

shows a peak in late November or early December arising from the requirements for the cereal and seed crops. This is in contrast to the maximum water use in existing schemes where, with less cropping, the peak usually occurs later in December or in January.

A profile of peak demands may be found by taking the highest demand simulated at any time during the 11 years for each period in the irrigation season. This is the combination of all worst cases. As shown in Fig 4.3 these peak demands follow a similar time pattern over the irrigation season but are between 6 and 15m³/s higher than the average demand profile for the 39,000 ha area examined.

The effect of the cereal and seed crops on peak water demands can be seen as an additional increment on top of the relatively constant requirements for roster irrigation of pasture and lucerne, the effect being most marked in December but also significant in November, January and February.

The results shown are for a roster cycle of 23 days for pasture and lucerne, a roster cycle length which economic studies indicate to be suitable for border-dyke irrigation in the Lower Rakaia area (Le Page and Ritchie 1980). Comparative analyses of 18-day, 23-day, 28-day and 33-day cycle lengths have also been carried out. These indicate that the seasonal average irrigation water demand decreases by 0.007 l/s.ha for each day the roster cycle is lengthened from 18 to 33 days.

The effect of altered cropping patterns on water demand was examined and irrigation of fodder beet, a potential energy farming crop, was also simulated. Roster irrigated pasture has the largest volume of seasonal water demand followed by rostered lucerne and then fodder beet irrigated on demand. Cereal and seed crops have small total demand volumes but larger peak demand rates corresponding to their moisture requirements at specific stages of growth.

Considerable changes in the crop distribution are required before changes in scheme water demand patterns become significant. A move from largely pastoral farming to increased cash cropping will decrease the volume of water demand but is likely to increase peak water demand rates, particularly in the November-December period. There is some small potential to reduce peak demands by staged planting of crops.

Under all-grass farming and with a long roster cycle the soil type does not strongly influence water demand because in dry periods plant water use is likely to deplete both deep and shallow soils to the extent that irrigation is required for all soil types. In practice under these conditions water is usually applied whenever it is available to preclude extreme moisture deficits being reached.

Soil type has a greater influence when irrigation is on demand rather than on a roster cycle. For irrigation of cereal and seed crops on demand, the frequency of irrigation simulated on the shallow soils is nearly double that on deeper soils.

Comparisons were made between simulated demands for the Lower Rakaia and Central Plains regions and the demand rates per unit area were found to be not greatly different. Hence it is considered that the results developed for the Lower Rakaia area can be applied in the Central Plains region also.

4.2 Water Availability for Irrigation

The Rakaia River is the major surface water resource in mid-Canterbury and an obvious source of water for irrigating the plains between the Waimakariri and Ashburton Rivers. This section is concerned with supplies for the Lower Rakaia and the Central Plains irrigation proposals (Fig 4.1). The Ashburton-Lyndhurst Scheme is already served by the Rangitata Diversion Race and it is assumed that the Barrhill area will also be supplied from that system.

In the Lower Rakaia and Central Plains areas some parts will be supplied with groundwater and others with river water so it has been necessary to consider a number of alternative supply arrangements. These alternatives were set up by dividing the Lower Rakaia scheme into seven segments (Fig.4.4) on the basis of the present pumping depths for groundwater supplies within each segment. Table 4.1 outlines six alternative supply schemes and their pumping depths for the Lower Rakaia area (64,000ha). Fig 4.5 shows the combined areas of the Lower Rakaia and Central Plains

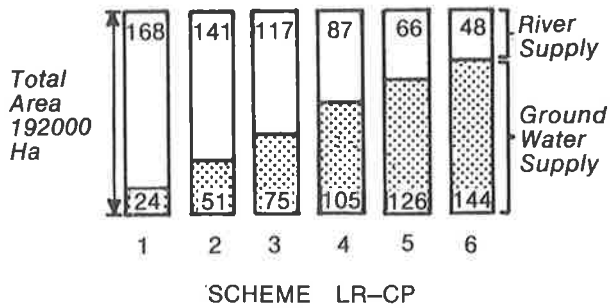


Fig. 4.5 Water supply alternatives for the combined Lower Rakaia–Central Plains areas

Scheme Designation	River Supply		Groundwater Supply		
	Segments	Area (,000 ha)	Segments	Area (,000 ha)	Maximum Present Pumping Depth (m)
LR 1	2-7	56	1	8	20
LR 2	3-7	47	1-2	17	20
LR 3	4-7	39	1-3	25	25
LR 4	5-7	29	1-4	35	35
LR 5	6-7	22	1-5	42	45
LR 6	7	16	1-6	48	55

NOTE: In describing a particular scheme alternative, prefix LR denotes Lower Rakaia and prefix LR-CP denotes the combined Lower Rakaia and Central Plains area.
Suffix 18, 23, 28 or 33 denotes the roster period used for border-dyke irrigation. So "LR-CP 3/28" is shorthand for supply scheme 3 to serve the combined Lower Rakaia-Central Plains area at a roster interval of 28 days.

Table 4.1 Alternative supply schemes for the Lower Rakaia area (64,000 ha) schemes (192,000ha) divided in the same proportions as for the Lower Rakaia area on its own. As the pattern of groundwater depths in the Central Plains and Lower Rakaia areas is not identical, further study could refine the proportions of the Central Plains area irrigable from groundwater.

River Water Supply

In its current allocation and management plan for the Rakaia River the North Canterbury Catchment Board (NCCB) recognised "that irrigation would be the major consumptive use of water available for allocation, that no industrial development was likely in the forseeable future, that the absence of waste discharges in the river placed no immediate constraints on allocation and management of the resource, and that the provision of a sufficient residual flow to maintain the fishery would accommodate most other recreational and ecological requirements" (North Canterbury Catchment Board 1974).

In this section it has been assumed that the water available for allocation under the NCCB plan as depicted in Fig. 4.6 would be available for the proposed Lower Rakaia and Central Plains irrigation schemes.

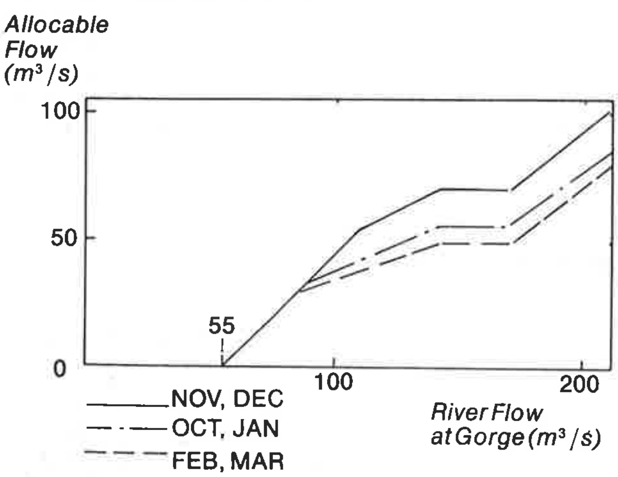


Fig. 4.6 North Canterbury Catchment Board Rakaia River Allocation Plan
(Source: North Canterbury Catchment Board 1974)

Method for Assessing the Adequacy of River Supply

As described by Philpott (1980) this is to:

1 **Estimate demand:** 100 percent irrigation development is assumed for the combined Lower Rakaia-Central Plains areas given in Fig. 4.5. The patterns of farming used are detailed by Le Page and Ritchie (1980). Potential water demands were estimated as described in section 4.1, from which daily demand rates m^3/s were calculated over September to April for the 11 seasons from 1967 to 1978.

2 **Quantify supply:** the water available for daily allocation in accordance with the NCCB Management and Allocation Plan for the Rakaia River was calculated from the river flow records for the same period, 1967–78.

3 **Compare demand with supply:** days when the river flow available for allocation was less than the potential demand rate were determined together with the amount of deficit. This was done for schemes LR-CP 2/23, 2/28, 3/23, 3/28, 4/23, 4/28 and 5/23, and also for some possible river flow management options discussed later.

Limitations of the Available River Flow

For most of the supply alternatives examined there were times when the available river water would have been insufficient for the potential irrigation demand. The extent of the deficits is summarised in Table 4.2.

Groundwater Supply

The quantities of water needed for the areas of the Lower Rakaia schemes which might be supplied from groundwater are indicated in Table 4.3. The figures were taken from the potential irrigation demands over the 11 seasons 1967–78 described in section 4.1.

Scheme	Area to be Supplied With Groundwater (,000 ha)	Peak Irrigation Demand (m^3/s)	Average Annual Demand (m^3/s)
LR 1/28	8	6	0.8
LR 2/28	17	12	1.9
LR 3/28	25	17	2.9
LR 4/28	35	23	4.0
LR 5/28	42	28	4.9
LR 6/28	48	32	5.5

Table 4.3 Potential irrigation demand on groundwater for Lower Rakaia Scheme alternatives

Planning Options

The prospect of significant deficits in the Rakaia River flows which could be available for allocation for the proposed irrigation development invites consideration of several planning options:

1. Plan for Maximum Use of Groundwater

The main advantages of maximum use of groundwater are:

Scheme		Area to be Supplied with River Water (,000 ha)	Peak Irrigation Demand (m^3/s)	% of Days with Deficiency		% of Volume Deficiency	
				Whole Season	February	Whole Season	February
LR-CP	2/23	141	109	24	54	11	25
	2/28	141	98	22	60	9	22
	3/23	117	89	15	47	6	16
	3/28	117	80	12	46	4	12
	4/23	87	67	4	21	1	4
	4/28	87	62	3	16	0.6	2
	5/23	66	50	0.3	3	–	0.3

Table 4.2 Deficiency of river flow available for irrigation
(Source: Philpott 1980)

least effects on river flows, independence of individual farm development programmes, and complex distribution and control systems are not needed.

The main disadvantages are: continuing high energy consumption; and the risk of exceeding the long-term safe yield which could cause progressive lowering of the water table, existing bores to become partially or totally ineffective, and salt water intrusion near the coast.

Precise limits on the capabilities of the groundwater resource are not yet defined in the Lower Rakaia area which is where the more intensive investigations are being conducted. However, as only 3-12% of the total recharge is at present being extracted it is reasonable to assume considerable further development is practicable.

2. Plan to Develop only Lower Rakaia or only Central Plains

If the demand from either of these areas alone had applied during the 11 years studied there would have been no significant deficit in the water available for any Lower Rakaia option or for Central Plains options 2 to 6.

3. Develop only a Proportion of Both the Lower Rakaia and the Central Plains Areas

This would be similar to the early mid-Canterbury schemes where the supply was planned to serve only half of each farm within the area commanded, although it has subsequently proved adequate for about 2/3 of the area.

4. Propose Adjustments to the Water Allocation Plan

To satisfy the full demands of scheme LR-CP 3/23 the river flow would have been reduced to about $30m^3/s$ for several days on three occasions in the period 1967-78. For schemes LR-CP 2/28 and 2/23 the river flow would have been lower still.

If schemes LR-CP 2 or 3 are adopted it might be preferable to confine any possible adjustment of the allocation plan to higher river flows and meet irrigation demands by increasing the effectiveness of storage management for low flows.

5. Tolerate Restrictions

Some restrictions in supply can be tolerated but the shortages of schemes LR-CP 2/23 and 2/28 and perhaps also 3/23 and 3/28 might reduce farmer confidence to the extent that farms would not be fully developed. With irregular water restrictions, the difficulties of irrigation farm management increase and the security of irrigation farming diminishes.

6. Plan for More Minor Schemes

Both Labour and National governments have adopted a policy for assisting full irrigation development. The programme for major schemes lists Lower Rakaia and then Central Plains to follow on after Waiau Plains which is now being constructed. Further major schemes could be shelved in favour of more minor schemes such as the existing North and South Rakaia schemes.

Fig. 4.7 shows estimates of future irrigation development under two policy options. The upper line assumes progress in accordance with present government planning timetables. The lower line assumes there are no further government sponsored community schemes but farmers continue their present development activities and that groundwater availability does not limit this development.

7. Plan to Use Lake Coleridge Storage to Augment Summer Low Flows

The locations of the rivers, diversion channels and the power station associated with Lake Coleridge are shown in Fig. 4.8 The records of Lake Coleridge inflows and outflows were reviewed for the 11 years 1967-78 to establish the extent to which the irrigation supply deficiencies could have been reduced by operating Coleridge Power Station at full load (35 MW) while the river was low.

It was assumed that none of the extra water was lost by seepage between the power station and the gorge. This is a realistic assumption if the river gravels become saturated and adjusted to a higher flow rate resulting from Coleridge releases. Such an adjustment might take several days. Two methods were used to allocate the extra water:

Method (1)
All the extra outflow from the power station was added to the river flow at the gorge which was then allocated according to the NCCB plan;

Method (2)
All the extra outflow from the Power Station was regarded as available for irrigation.

The results were significant in both cases but especially for Method 2. Some of the effects on the irrigation supply for the largest river supplied scheme, LR-CP 2/23, are set out in Table 4.4.

	% of Days with Deficiency		% of Volume Deficiency	
	Whole Season	February	Whole Season	February
Gorge flows	24	54	11	25
Method 1	18	49	8	20
Method 2	10	32	3	8

Table 4.4 Potential effects of changed Lake Coleridge Power Station operation on irrigation supply deficiency for Scheme LR-CP 2/23
(Source: Philpott 1980)

During the years 1967-78 the most serious deficiency in availability of river water for irrigation occurred in the 1972-3 season. However, the lake was within a metre of being full from November 1972 to March 1973 and all the extra water required to supplement the deficit could have come

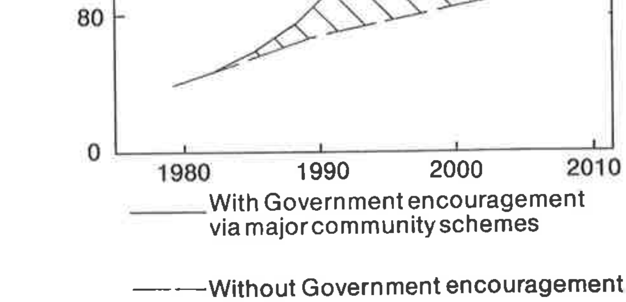


Fig. 4.7 Projected irrigation development rates in the Rakaia region

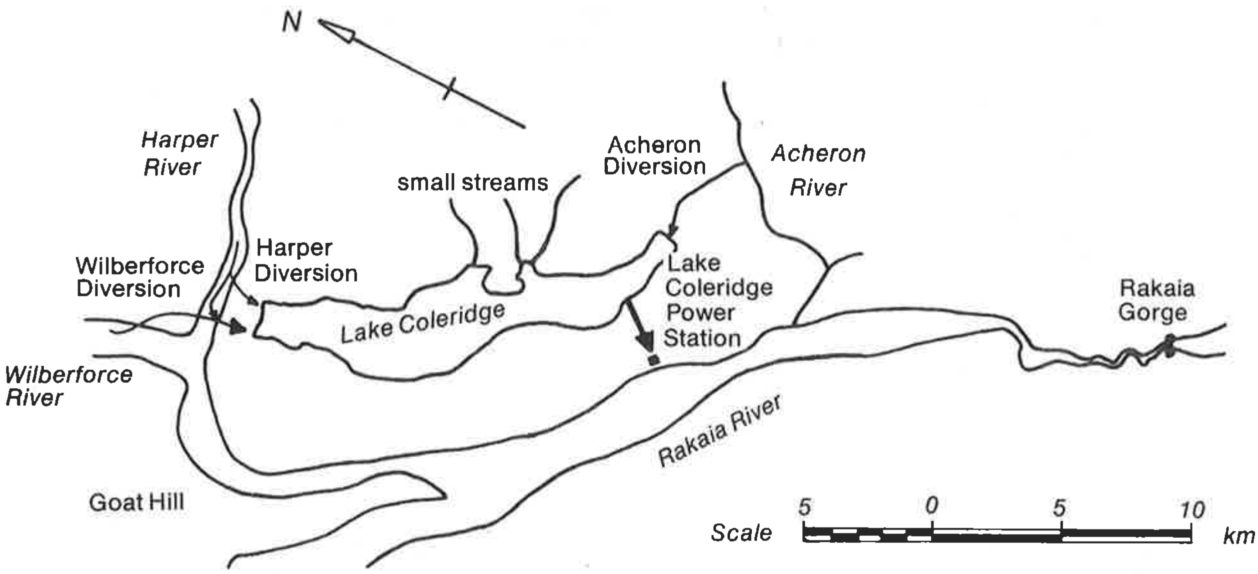


Fig. 4.8 Diversions and outlet to Lake Coleridge
(Source: Philpott 1980)

from water already stored in the lake.

This may have entailed forgoing some power generating capacity during the winter of 1973 to ensure the lake was full for the following irrigation season. It does, however, demonstrate the potential for manipulating lake storage to offset irrigation deficits. The potential effects of the different methods of allocating the extra flow from storage during January, February and March 1973 are illustrated in Fig. 4.9.

The Wilberforce Diversion constructed in 1977 (Fig. 4.8) has already effected some improvement in summer low flows in the Rakaia River. The improvement results from increased capture and storage of flood runoff which is used for more continuous generation throughout the whole year including periods of low summer flow.

Other possibilities for augmenting low river flows include: (a) reducing river diversions into Lake Coleridge at times of critical low flow; (b) increasing lake outflow via the existing lake outlet (possible only when the lake is nearly full), or via new tunnels and plant at Coleridge Power Station; (c) increasing Lake Coleridge available storage with a dam at Goat Hill, or lower tunnels to a modified power station; (d) increasing the capacity to divert river flow into Lake Coleridge; or (e) pumping to storage in Lake Coleridge from Rakaia River freshes.

These options need consideration against the time scale of 30 to 50 years for completing the irrigation development.

Coordination with Power Development

There will be the opportunity and need to plan multi-purpose water storage management for best water use. The Southern Energy Group (1976) has made a number of proposals for joint irrigation and power developments from the Rakaia River. For the next decade or so it is possible to programme the irrigation development without specific decisions on power development. The proposed Lower Rakaia irrigation development is not directly dependent on any power proposals. The first stage of the Central Plains irrigation development could be supplied from the Rakaia River with a temporary intake at tailwater level for the lowest power station proposed for the north bank of the Rakaia River, thus divorcing it from major decisions on future power development.

4.3 Social and Environmental Effects of Irrigation Development

The environmental effects of the proposed irrigation development are likely to appear gradually in stages over a number of years starting with the Lower Rakaia area in the first decade. By the second decade work could be in progress on the lowest section of the Central Plains area with subsequent stages moving further up the plains and supply arrangements being integrated with power developments.

Social Effects

Early Canterbury irrigation schemes were promoted with the expectation that considerable increases in rural population and prosperity would result (Public Works Department 1945). Although the actual changes were not as dramatic as anticipated, evidence exists of an intensification of rural activity and stimulation of associated population centres when irrigation development occurs quickly.

Hubbard and Brown (1979) present population data for rural and urban communities around the Lower Waitaki and Morven-Glenavy irrigation schemes which show an increase in population of 3-5% from 1971-76 as irrigation development occurred, compared with decreases of 1-7% from 1966-71. Hubbard and Brown consider that most population and employment effects of irrigation development there occurred in the urban communities supported by the agricultural activity, rather than in the rural areas themselves where the farmers tend to work longer hours rather than take on extra labour.

Evans (1977) has shown that on the Ashburton-Lyndhurst scheme few additional farms were created as a result of irrigation but there was an increase in the density of settlement.

Morton (1978) describes some of the social effects of irrigation development:

> "School rolls and population numbers increase partly because farmers near retirement age, who live where an irrigation scheme is being established, sell out to younger

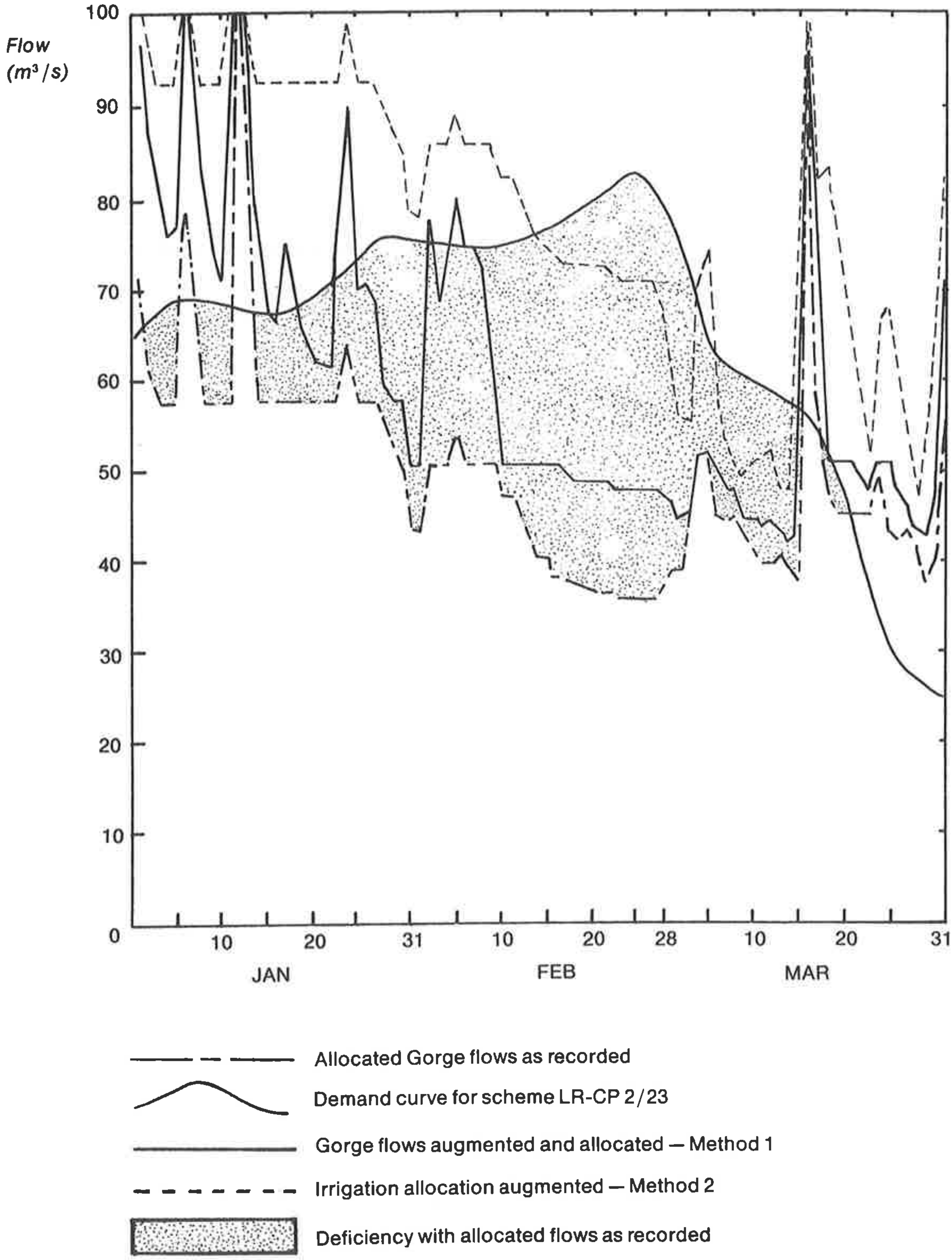


Fig. 4.9 Potential effects of changed Lake Coleridge Power Station operation (Conditions of January-March 1973)
(Source: Philpott 1980)

men with families. Young irrigators are vigorous enough to face the new work, flexible enough to welcome changed methods, and confident enough to shoulder immense debts. Some of the early increase in population is not always maintained as these young families grow up. But other people come because the local towns often find it possible to begin processing the stable and plentiful production of the area.

"A spiral of growth begins upon a stable production and income base, just as a spiral of decline has begun in so many of our rural areas where such conditions do not exist."

Effects on the Landscape

Existing irrigation development in Canterbury has shown that farmland will become more finely subdivided as development occurs with more frequent shelter belts and a greater variety of timber, fruit and ornamental trees.

In some parts of the river the irrigation intakes and races will noticeably modify the landscape.

Effects on the Rakaia River

The main effects on the river will result from reduced river flow, changed surroundings at intakes and main races, and altered access facilities. The major interests which will be affected by such changes include fisheries, wildlife habitats, and recreational activities.

The first major irrigation abstraction is likely to be for the Lower Rakaia scheme and it will affect the lower 35 km of the river. Subsequent abstraction for the Central Plains scheme will affect more reaches of the river up towards the Gorge.

The North Canterbury Catchment Board's water allocation plan was developed so that irrigation abstractions would not cause major harmful effects on the river. Although at present the environmental effects of reduced flow are not completely clarified, as research continues better evidence will become available for quantifying these effects. To gain a more complete understanding of the phenomena associated with reduced flows in braided channels, further studies are being carried out both by MAF Fisheries Research, MWD Water and Soil staff, and others, with particular emphasis on conditions in the lower reaches of the Rakaia River.

Abstractions will have little effect on flood flows and the major sediment transport mechanisms, but they will reduce flows during freshes to a small extent. Abstractions will have greatest effect at low river flows. The subtle changes in patterns of low flows in braided channels are not well understood, but they have potential effects on all freshwater life and associated life forms as well as the passage of migrating fish.

Fig. 4.10 indicates how abstractions for some irrigation alternatives affect residual river flows, assuming the water is taken out at the Gorge.

The possible effects of flow reduction on fish in the Rakaia River have been discussed by Davis (1979) and include reduction of habitat, increased water temperature, restrictions on fish passage, increased sedimentation and also possible stranding of fish if flows fluctuate rapidly with adjustments of withdrawals. These effects will be most severe in the lower reaches of the river where most braiding occurs and river losses and abstractions will have their maximum effect.

The reductions in flows during freshes are shown in Tables 4.5 and 4.6 for the largest river-supplied scheme considered, LR-CP 2/23. These tables show that even for such a large scheme there would be very little alteration to the patterns of freshes having flows of 200 m^3/s or more.

The use of jet boats and canoes will be most affected in the lower reaches of the river although care may be needed to ensure adequate passage in the vicinity of the intake structures further up the river. Food and breeding site availability for wildlife may be affected by reduced flows.

There is also the possibility that the cycle of river mouth openings to the sea may be affected by patterns of reduced river flows. Kirk *et al.* (1977) suggested that this could cause a loss of recreational and wildlife amenities and some increased flood risk on the land adjacent to the lower channels.

Some wildlife habitats may be affected by irrigation development, and improved access to the river may be harmful to those specialised birds such as the wrybilled plover which nest on the broad, open, shingle river bed.

Design Considerations for Recreation

Douglass *et al.* (1979) discussed the possibility of combining extra recreational opportunities with the proposed irrigation developments. They pointed out the possibilities of providing for a number of water-based recreational activities such

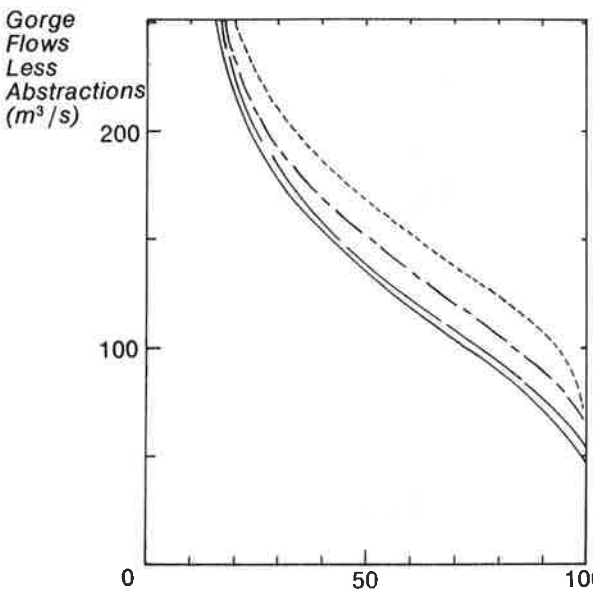


Fig. 4.10 Effect of irrigation abstractions on Rakaia River flows
(Source: Philpott 1980)

Flow (m^3/s)	Interval between Freshes (days): Without Abstraction	With Scheme LR-CP 2/23
300	18.3	21.9
200	12.5	14.8
100	6.0	8.5

Table 4.5 Average interval between freshes (Average number of consecutive days that river flow is *less* than the listed flow during the irrigation season)
(Source: Philpott 1980)

Flow (m^3/s)	Duration of Freshes (days): Without Abstraction	With Scheme LR-CP 2/23
300	2.1	1.8
200	5.3	3.8
100	41.7	18.8

Table 4.6 Average duration of freshes (Average number of consecutive days that river flow is *more* than the listed flow during the irrigation season)
(Source: Philpott 1980)

as fishing in irrigation races, canoeing, rowing and swimming. Other non water-based activities which might be additionally catered for include sightseeing, picnicking, walking, cycling, horseriding and shooting.

Large parts of the irrigation reticulation system could be useful for fish and recreational purposes. Salmon fry released in selected irrigation races could grow to smolt size before downstream migration. The Lower Rakaia intake structure and settling ponds located below Barrhill could be laid out in such a way that picnic, swimming and minor boating facilities, and good river bank access are provided. A canoe and rafting course might be incorporated in a larger, steeper irrigation race in the Lower Rakaia reticulation system near Chertsey. Modification of some structures or races may make them suitable wildlife habitats, especially for waterfowl. Douglass *et al.* (1979) pointed out that enhancement of water recreation opportunities around Barrhill would appear to fill a need for such facilities in that area.

General Considerations

There is a possibility of diverting more continuous flows into ephemeral streams such as the Selwyn River and its tributaries (Hughey 1980). This would tend to change the whole stream environment and stabilise the adjacent water table as has occurred with such rivers as the Hinds River since it was augmented with Rangitata River water via the Mayfield-Hinds and Valetta irrigation schemes.

All these possibilities will justify careful consideration along with irrigation planning. Current ideas will need to be developed and modified by discussion and planning with appropriate contributions by Government, local bodies and the various organisations interested or affected. Fig. 4.11 shows the various stages in the planning process at which some response may be needed from the relevant local bodies and also where interested groups or individuals may make submissions.

4.4 Economics of Irrigation Development

Irrigation development affects the interests of many individual farmers as well as the nation as a whole. The farmers of any region usually have a range of differing economic circumstances from wealthy holdings to marginally economic properties. These differing economic circumstances tend to generate differences in attitudes towards development opportunities.

In a drought prone region, all farmers may be interested in the possibility of irrigation, but not all for the same reasons. Some may see irrigation as an opportunity for expanding their enterprise through borrowed capital and will take an optimistic view of the hazards of cost and price fluctuations and the frustrations of industrial unrest and international politics. Others will be more interested in reducing the effects of drought on production and less willing to accept the risks of relying heavily on borrowed capital for major development.

The ideal situation for all farmers would be to have a low cost source of water on each property so that each farmer could develop irrigation in his own time and at a pace to suit his own economic circumstances. This is the situation which has existed in those parts of the region which have shallow, free-flowing groundwater. In other parts, where groundwater or nearby surface water is not readily available, a supply for each individual farm is an economic possibility only through community schemes.

For the nation as a whole it is desirable to see all regions of the country flourishing and contributing generously to the national economy, but early irrigation schemes were disappointing because of the slow rate of farm development within the schemes.

This is well demonstrated in Fig. 3.2 which shows the slow, steady development of the Ashburton-Lyndhurst scheme averaging only one percent of the area per annum. Such slow realisation of the potential irrigation benefits is unattractive from the nation's view point. Many other forms of resource development give much quicker returns for the taxpayers' investment and are, therefore, preferred. Nevertheless, there is general agreement that irrigation is a worthwhile resource development.

Over the years a national policy for new community irrigation schemes has been evolving with two major objectives:

(a) To ensure that, before committing a new scheme, most of the farmers involved are keen to undertake irrigation development or will stand aside and let others;

(b) To encourage rapid farm development, and so to shorten the time lag between incurring construction costs and realising the scheme benefits.

The economics of national development proposals are usually assessed by cost-benefit analysis. Streams of costs and benefits through the years are discounted to present values. The interest rate at which the present value of all costs is equal to the present value of all benefits is the internal rate of return (IRR). As at March 1980 an internal rate of return of 15% was regarded as acceptable for major irrigation projects although it is common for individual farm irrigation development to show much higher rates of return.

Economic Studies

Over the last few decades, the irrigation schemes and proposals in the Rakaia region have been subjected to a number of economic studies. Stuart and Tocker (1957) prepared estimates of the effect of a proposed irrigation scheme between the Waimakariri and Selwyn Rivers. They compared present conditions (1956), with potential (1966) dryland, and potential (1966) irrigation, of 59,000 ha (145,000 ac). Their results are summarised in Table 4.7.

		Potential	
	Present (1956)	Dryland (1966)	Irrigation
Ewe Equivalents	260,000	400,000	700,000
Wool (Bales)	7,540	12,560	21,750
Fat Lambs	203,000	290,000	471,000
Revenue £ (1956)	£1,000,000	£1,600,000	£2,600,000

Table 4.7 Summary of present (1956) and potential (1966) stocking and production for the Waimakariri – Selwyn irrigation proposal
(Source: Stuart and Tocker 1957)

Stewart (1963) compared the profitability and productivity of irrigated and non-irrigated farms in the Ashburton-Lyndhurst area. He examined profitability in terms of "owner surplus", and productivity in stock units per acre. He concluded it was doubtful whether irrigation could be justified under the technologies then current but indicated that the advent of automatic irrigation, or a swing to intensive cropping, or sharp increases in sheep product prices could change that conclusion.

Hadfield *et al.* (1974a, 1974b) carried out comprehensive

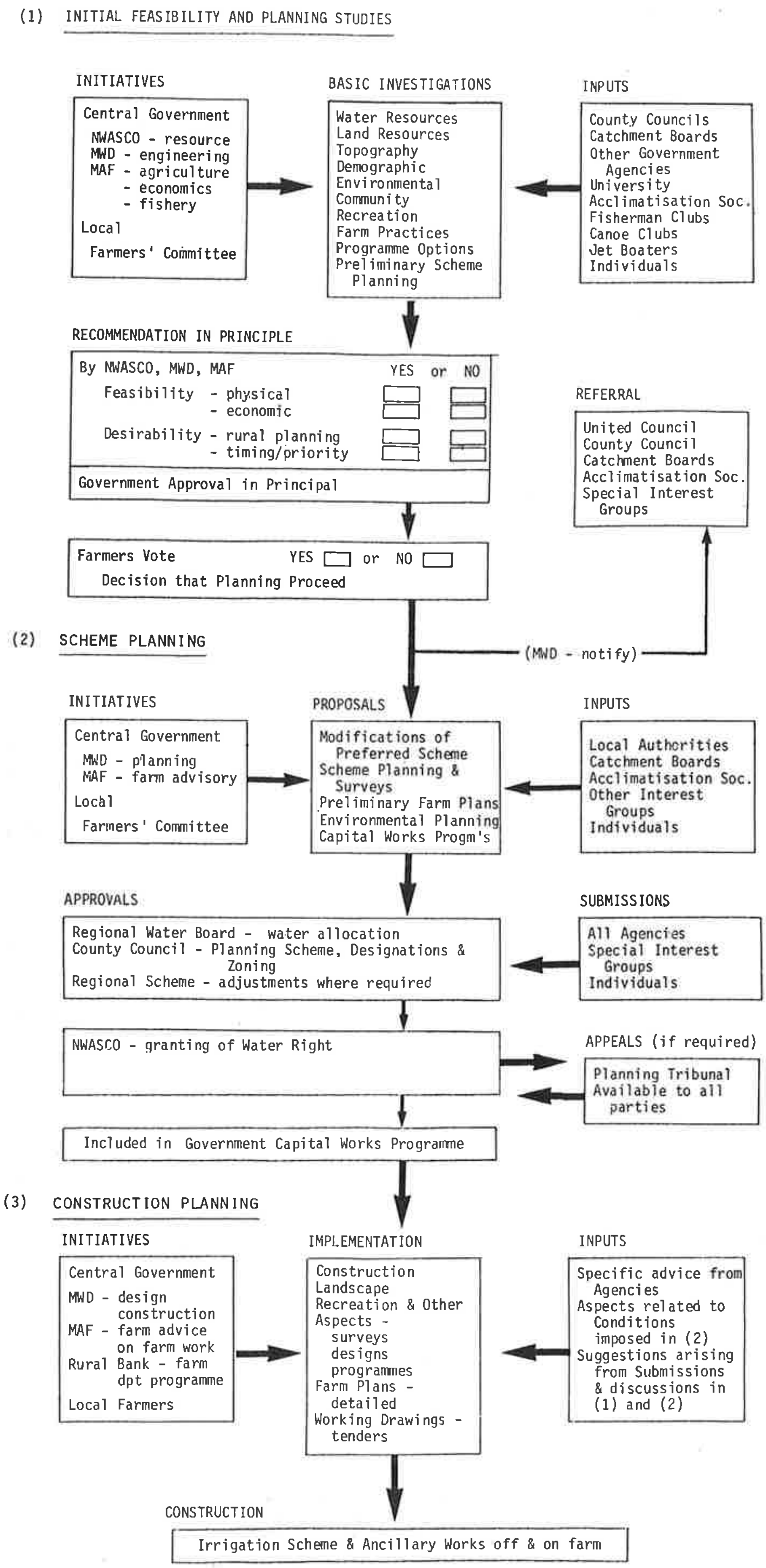


Fig. 4.11 Irrigation Planning Sequence
(Source: Douglass et al. 1979)

Type of Farming	Dryland	Irrigation		
		Extensive	Moderate	Intensive
Proportion of area in crop (%)	22	25	28	34
Proportion of area irrigated (%)	-	36	53	79
Stocking rate on winter grazing (stock units/ha)	8.9	12.4	14.1	16.1
Internal rate of return at $247/ha ($100/ac) off-farm cost (%)	-	6.4	9.3	11.6
Estimated peak flow (m^3/s)	-	19	27	37

Table 4.8 Economic analysis of the Lower Rakaia area
(Source: Hadfield et al. 1974b)

cost-benefit analyses for both the Lower Rakaia and Central Plains areas. The scheme areas were divided into nine groups on the basis of soil type and farm size. Nine representative farms were then budgeted for likely grazing and cropping programmes under dryland conditions and three intensities of irrigation. Sensitivity tests were carried out for rate of development and off-farm cost variations and their results are summarised in Table 4.8.

Frengley (1979) studied the water demand associated with irrigation investment for 287 farms totalling 68,000 ha in the Lower Rakaia area. Fifty-eight farms were surveyed representing three size groups on each of three soil types. His objective was to maximise net farm revenue in an average season by selecting optimal irrigation programmes for each farm size on each soil type when varying quantities of water were used. He showed how small percentages of irrigation development can be highly profitable and that the irrigation benefit tapers off markedly as complete development is approached.

Le Page and Ritchie (1980) have highlighted the economic advantages of irrigation development using groundwater even when it must be pumped from 60 m or more with high energy costs. There are physical limits to the total safe withdrawal from groundwater and these limits have yet to be established for the Rakaia region.

Le Page and Ritchie studied the six groundwater-river water supply alternatives for the Lower Rakaia area which were described in section 4.2 and found that the use of pumped groundwater with sprinkler irrigation was more economic than border-dyke irrigation with river water even when quite high energy costs were involved. This conclusion stemmed firstly, from the small time lag between the development investment and the resulting benefits as compared with the delayed returns from a gravity river diversion scheme, and, secondly, from the small capital costs of groundwater supply.

They also showed that the economic return to either the Lower Rakaia area as a whole, or to the groundwater or river water sections individually, was not very sensitive to the boundary chosen for the two supply sections. The economics of the river section improved marginally as its area was expanded and the headworks costs were spread more widely. The economics of the groundwater section improved, also marginally, as its area was reduced and the mean pumping depth became less.

Le Page and Ritchie (1980) showed further that within the range studied the economic return was not very sensitive to the frequency of irrigation. As the roster interval was increased from 18 to 33 days the decreasing costs were matched by decreasing benefits. The optimum roster interval on pasture appeared to be about 18 to 23 days for border dyke irrigation and about 28 days for spray irrigation.

Rate of Development

Hadfield *et al.* (1974b) showed how the economic returns of an irrigation development are sensitive to the rate at which the land actually becomes irrigable (Table 4.9).

Development period (yr)	7.0	10.0	15.0
Development rate (%/yr)	14.3	10.0	6.7
Internal rate of return (%)	11.3	10.5	9.5

Table 4.9 Sensitivity of the internal rate of return to rate of irrigation development in the Lower Rakaia area
(Source: Hadfield et al. 1974b)

Although the development rates shown in this table are much faster than the 1%/yr achieved on the earlier Ashburton-Lyndhurst scheme, recent schemes have developed more rapidly as a result of changed government policies. The Morven-Glenavy scheme, which was approved for construction in 1970 and began operating in 1974, achieved a 10%/yr development rate (Fig. 4.12).

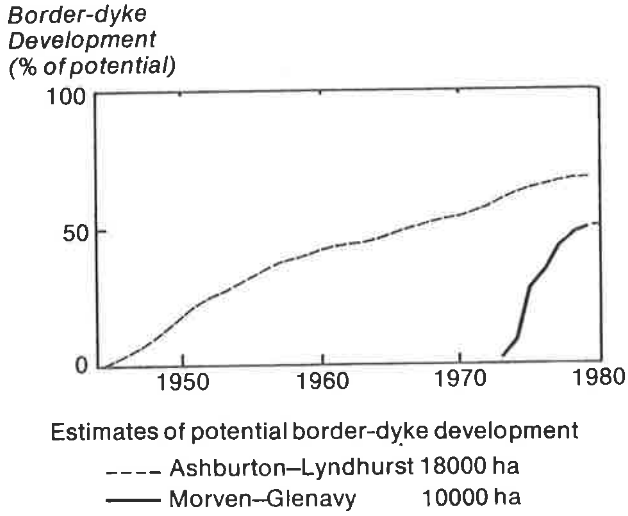


Fig. 4.12 Border-dyked land development on the Ashburton–Lyndhurst and Morven–Glenavy irrigation schemes

Since 1974 the policy for new schemes has been further modified to allow capital advances with suspensory loans for on-farm development in accordance with approved plans and programmes.

In North Canterbury, the Waiau Plains scheme serving 17,000 ha is now being constructed and the first water should become available in 1980. It is expected that the rate of development at Waiau Plains will show a further improvement on Morven-Glenavy. By September 1979 farm development plans and programmes for 8,183 ha and border-dyking of 740 ha had been completed. A further 1,000 ha of border-dyking is programmed for each of the next three seasons on those farms with completed plans. These early rates of development will average about 12% per annum and development rates for the rest of the farms are likely to be similar when their plans and programmes have been finalised.

Regional Effects

Hubbard and Brown (1979) studied the regional impact of the Morven-Glenavy and Lower Waitaki irrigation schemes from 1970 to 1978. They concluded that there were injections to the regional economy in this period of $11.2M spent in irrigation construction, and $8.7M worth of extra agricultural goods produced as a result of irrigation. They estimated that this $19.9M of extra revenue generated in the region an additional revenue of $20.7M as the ripple effects of the direct injection spread through the regional economy. They indirectly estimated the effect on employment in the region as an increase of 439 full-time jobs, mostly associated with agricultural supply and processing activities rather than on-farm work.

5 Summary and Conclusions

The region in which Rakaia water resources could be further utilised for irrigation development has been studied. This covers 3600 km^2 of the Canterbury Plains between the Ashburton and Waikmakariri Rivers, and between the Alps foothills and the sea.

This report surveys the climate, water, land, biological and historical resources and the population distribution of the study region; summarises the use currently being made of these resources for irrigation, fishing, recreation, power generation, and rural water supply; and describes the scope and implications of potential large-scale irrigation developments.

The salient features of the resources are:

(a) **Climate.** The climate is dominated by the effect of the Southern Alps as they intercept the weather systems approaching from the west. Rainfall averages from 700 mm/yr near the coast to 1000 mm/yr near the foothills and is evenly distributed throughout the year. Monthly rainfalls recorded at Winchmore vary from a fifth to three times the long-term monthly averages. Average monthly air temperature varies between 5°C in July and 16°C in January but the range between the mean monthly minimum and the mean monthly maximum exceeds 20°C in all months. Potential evapotranspiration exceeds average rainfall from October to March. Wind run averages 290 km/day with no dominant direction. Snowfalls are infrequent and snow seldom remains on the ground for more than a day or so.

(b) **Water resources.** The major water resource of the region is the Rakaia River with a mean annual flow of 196 m^3/s which makes it the largest river flowing across the Canterbury Plains. It has a seasonally varying flow pattern with the maximum monthly mean flow in November and the minimum in July. Low flows do not vary greatly over the year with the flow level exceeded 90% of the time ranging from 90 m^3/s in August to 145 m^3/s in December at the Gorge recorder site which has the only long term flow record available. The flow records from 1957–78 at this site have been retrospectively analysed to better account for the unstable nature of the riverbed at the recorder site and resultant flow data given in this report supersede earlier figures. Instantaneous flows ranging from 77 m^3/s to 3545 m^3/s have been recorded at the Gorge. Lakes Coleridge and Heron are the only significant surface water storages in the Rakaia catchment. The Selwyn is the only other significant river flowing across the region.

The Rakaia is a braided, shingle river. The number of braids increases from an average of 10 near the gorge to 20 near the sea but the total width of flow shows little consistent trend along this reach of the river. Field measurements made in the region of greatest braiding show that the channels are unstable even during the steady low flows of the winter period.

Groundwater underlies the entire Rakaia region. Near the rivers and the sea the water table is within a few metres of the ground surface, but inland it recedes to more than 70 m below the surface. Estimates of the total average flow through the groundwater aquifers of the region range from 20 to 70 m^3/s. The two sources of groundwater are seepage from rivers, and drainage from irrigation and rainfall. Some evidence of nitrate pollution of groundwater exists.

(c) **Land resources.** The land resources of the region are based on great depths of glacial outwash gravels formed into interleaving layers, and overlaid near the rivers by postglacial alluvium. About 75% of the soils of the region are shallow or stony silts less than 0.5 m deep with the remainder being sandy or silt loams ranging from 0.5 m–1.2 m deep. The main features of the landscape in the region are the gorge and upper river terraces, and the plains with the mountains as a backdrop.

(d) **Biological resources.** The main biological resources of the region are its fish, bird life, and vegetation. Of the 21 fish species known to inhabit the river, more than half are migratory and spend part of their life cycle at sea. Seven species are found only in the estuary or the first few kilometres of the river. A quantitative understanding exists of the behaviour of the quinnat salmon, the most important species for sport fishing, and a qualitative understanding exists of the life cycles of the other fish species.

Of the 43 bird species in the region, 4 species use the broad, open shingle river bed of the Rakaia and other eastern South Island rivers as their main breeding ground. The wrybilled plover is the most notable of these species. Birds, fish, invertebrate animals, aquatic plants, and micro-organisms are interlinked in a complex food web. A scientific reserve which contains a wide variety of native vegetation formerly more common throughout the region has been established at the top of Great Island in the Rakaia River.

(e) **Historical and archaeological resources.** These are located throughout the region with many archaeological sites along the coastlines arising from maori and moahunter activities of centuries ago. Very few of these are near any potential irrigation construction sites.

(f) **Population distribution.** This is dominated by Christchurch and Ashburton. From 1961 to 1971 the Canterbury region's rural population decreased by 20%.

The major uses of the water and related resources are:

(a) **Irrigation.** At present some 35,000 ha of the region are being irrigated, 40% in community irrigation schemes, and the remainder in private developments, mostly using groundwater for spray irrigation. During the major part of the irrigation season the average water use rate is around 15 m^3/s, about half of which is withdrawn from the Rangitata Diversion Race and most of the remainder from groundwater aquifers. The irrigated area is expanding at the rate of 260 ha/yr within the existing major community scheme using river water (Ashburton-Lyndhurst), about 1%/year of the total area commanded by the scheme. Irrigation from groundwater and in small community schemes has been expanding at a more rapid rate during the 1970's. At present annual groundwater abstraction is around 10–15% of annual recharge, while abstraction for irrigation from the Rakaia River is less than 0.5% of the mean annual flow.

(b) **Fishing.** Fishing is the major recreational activity in the Rakaia River. The annual angling licence sales of the North Canterbury and Ashburton Acclimatisation Societies totalled 18,600 in 1978, together with 2,600 sales of daily or weekly licences. This indicated that there are approximately 20,000 anglers in North and Central Canterbury. A 1976 survey of the North Canterbury Acclimatisation Society concluded that its members rate the Rakaia River second in importance as a fishery after the Waimakariri River below the Gorge, with 38.8% of the survey respondents using it at least once in a season. Quinnat salmon are the prime sport fish in the Rakaia River with trout, flounder, whitebait and kahawai also being caught. Angling licence sales by the North Canterbury Acclimatisation Society are increasing at the rate of 330 per year, or 2% of 1977/78 total licence sales.

(c) **Recreation.** Besides fishing, significant recreational use is made of the Rakaia River for jet-boating, canoeing, picnicking and swimming. A 1979 survey of the 530 member Canterbury Branch of the New Zealand Jet Boat Association indicated that the whole length of the Rakaia River is used for jet-boating with the areas near the sea and at the gorge being the most popular. Salmon fishing is the most popular activity associated with jet-boating. Canoeing on the Rakaia River is concentrated near the Gorge. The Rakaia River supports some swimming and picnicking, but other locations within the study region are in greater demand for these activities than the Rakaia River itself.

(d) **Hydro-electric power.** Two power stations discharge water into the Rakaia River, Lake Coleridge (35 MW) and Highbank (25 MW). Average water use from 1958–1978 at these stations was 15.6 m^3/s and 12.5 m^3/s, respectively. In the past, the effect of storage of diverted river water in Lake Coleridge has been to partially retain summer flood flows for discharge during the winter. With the addition of the Wilberforce diversion in 1977 the lake has been maintained at a constant high level so the flow patterns downstream at the Gorge now tend to approximate the natural flows. The Highbank station, which uses water transferred from the Rangitata River, generates mostly during the winter when water in the Rangitata Diversion Race is not needed for irrigation.

(e) **Rural water supply.** Rural water supplies of 2.4 m^3/s are withdrawn from the Rakaia River to supply 70,000 ha via open stockwater races. When current proposals to pipe these supplies are carried out this water abstraction will be reduced by at least 80%.

Planning for irrigation development. Irrigation development might be extended from the current 35,000 ha to 220,000 ha in the Rakaia region over the next 3 decades. The implications of this include:

(a) **Potential irrigation water demands.** The irrigation water demand patterns were analysed using a computer simulation of soil moisture balance employing the 11 years of daily meteorological data recorded from 1967-78. These simulations indicate that the movement from pasture to more intensive cropping is likely to increase peak demand rates but decrease the volume of water used over a season, with the peak demands likely to occur in the November-December period. Variations in irrigation water demands are dominated by the rainfall pattern in a particular year, with the crop type and soil type having a lesser influence. For one possible development option in the Lower Rakaia area of 39,000 ha irrigated, the peak demand for river water in the 11 years simulated is 30 m^3/s and the average rate around 15 m^3/s over an 8-month season.

(b) **Water supply.** Using a second simulation model the balance of water supply and demand over the 11 year period was studied. Within the current Rakaia allocation plan about 100,000 ha could be irrigated in community schemes without there being significant deficits in supply provided that all the allocable flow is available for irrigation. Greater areas could be supplied if storage opportunities centred on Lake Coleridge were more fully utilised or if restrictions were tolerated on irrigation water supply during low flow periods, particularly during February.

The extended use of groundwater would appear to be essential if development of all potentially irrigable land in the region is to be achieved. Groundwater supplies could support 50,000 ha or more of irrigation.

(c) **Environmental effects.** The main environmental effects on the Rakaia River of abstraction for major community irrigation schemes would arise from diminished low flows and from local effects around the intake structures. Potential alterations to the flow patterns have been quantified. It is considered that, keeping within the current river allocation plan, no evidence exists at present that major adverse environmental effects will result from irrigation abstraction.

However, diminished low flows may decrease and change the water environment available for wildlife habitat and make the movement of fish species or jet boats along the river more difficult. Intake structures could partially obstruct fish and boat movement. Bird habitats could also be disturbed. Against this there are opportunities for environmental and recreational enhancement associated with using irrigation canals and ponds as fish habitats and recreation sites.

Adverse environmental effects are most likely to occur in the lower reaches of the river from State Highway 1 to the coast where flow will be lowest after upstream abstraction and seepage, where the river is braided into a large number of small channels making boat and fish passage more difficult than upstream, and where the greatest number of fish species are either resident, or use the reach as a migratory passage. The most likely time for adverse effects is late summer when river flows are falling, peak irrigation demands could still occur, and the salmon run in the Rakaia River is near its maximum. However, the flows near the coast would have to be greatly diminished to be as low as those on the Rakaia River above the Wilberforce confluence which is also a part of the salmon migration passage.

(d) **Economic effects.** Economic analyses carried out over the past 25 years have affirmed that irrigation in the Rakaia region can be economically beneficial to the farmer and the nation. A rapid rate of development of irrigated land from the time water first becomes available to the farm, so that benefits may be quickly realised, is a critical element in determining economic viability. In recent years new Government policies for community irrigation schemes have resulted in much quicker development rates than those previously achieved. Economic analysis indicates that irrigation development using groundwater is economically viable at 1979 energy prices when sufficient water can be pumped from up to 60 m depth.

The major new contributions to knowledge of the water and related resources of the Rakaia River from the studies carried out in 1978-79 and summarised in this report are:

* better understanding and more accurate data on the flow patterns in surface and groundwater resources in the Rakaia region;
* a clearer description of the river geomorphology and braiding patterns;
* an improved understanding of the fish of the Rakaia River;
* integration of data on major water uses on the Rakaia River;
* the investigation of likely patterns of irrigation water demand and their balancing against available supplies and methods to assess the effects of restrictions in irrigation water supply;

* a preliminary assessment of the environmental effects associated with major irrigation developments on the Rakaia River, including possible landscape, fishery and recreational changes; and
* a survey of economic analyses of irrigation development in the Rakaia region.

Areas where further research is needed include:

* the relation of channel patterns and other environmental parameters to flow rates in the river;
* quantitative data on the effects of low flows on the fish, birds and smaller organisms inhabiting the river;
* procedures for economic analysis to better account for the variability of agricultural production from year to year in response to different weather patterns;
* field information on actual irrigation water use rates and efficiencies;
* groundwater flow patterns and safe yields; and
* irrigation water scheduling to optimise the productivity of water use.

6 References

Adams, J. A.; Campbell, A. S.; McKeegan, W. R.; McPherson, R. J. 1979: Nitrate and chloride in groundwater, surface water and deep soil profiles of central Canterbury, New Zealand. *Progress in Water Technology 11 (6)*: 351–360.

Ayrey, R. B. 1971: The Rakaia catchment. *Water Usage Report No. 4.* North Canterbury Catchment Board, Christchurch, NZ.9p.

Boud, R.; Cunningham, B. T. 1957: A survey of salmon sport fishery in the Rangitata, Rakaia, and Ashburton Rivers. *Investigation Report – Job No. 3.* Freshwater Fisheries Advisory Service, NZ Marine Department. 10p.

Bowden, M. J. 1974: The water resources of the Waiau catchment. North Canterbury Catchment Board, Christchurch, NZ. 65p. + Appendices.

Bowden, M. J. 1977: The water resources of the Hurunui catchment. North Canterbury Catchment Board, Christchurch, NZ. 102p. + Appendices.

Broadhead, R. G.; Hutchinson, P. D. 1980: Areal demand aggregation model (ADAM) user's guide. *Water and Soil Science Centre Report WS183.* Ministry of Works and Development. Christchurch, NZ.

Canterbury Regional Planning Authority 1977: Regional policy no. 7: rural areas: needs of urban form. *Report No. 226.* Canterbury Regional Planning Authority, Christchurch, NZ.

Combined Christchurch Canoe Clubs 1979: Submissions to the North Canterbury Catchment Board Water Committee planning proposals for the Hurunui River. Combined Christchurch Canoe Clubs, Christchurch, NZ.

Cox, J. E. 1978: Soils and agriculture of part Paparua County, Canterbury, New Zealand. *NZ Soil Bureau Bulletin 34.* Department of Scientific and Industrial Research, Wellington, NZ. 128p.

Dalmer, E. B. 1971: The Waimakariri River as a water resource. North Canterbury Catchment Board, Christchurch, NZ. 54p.

Davis, S. 1979: Fish and fishery values of the Rakaia River – a preliminary report. Internal Report, Fisheries Research Division, Ministry of Agriculture and Fisheries, Christchurch, NZ. 55p.

Donaldson, I. 1977: An analysis of groundwater data from the Waimakariri-Rakaia region of the Canterbury Plains. Paper presented at NZ Hydrological Society Annual Symposium, Christchurch, NZ. 13p.

Douglass, M.; Robson, S.; Wilson, A.; Worth, M. 1979: Rakaia water use and irrigation development: recreation, landscape, planning. Joint report by Gabites, Alington and Edmondson, consultants; and MWD Environmental Design Section, Ministry of Works and Development, Christchurch, NZ. 98p.

Egarr, G. D.; Egarr, J. H. 1978: Canterbury canoeist's guide New Zealand Canoeing Association, Auckland, NZ. 68p.

Evans, B. M. 1977: The effect of irrigation on light land development in mid-Canterbury. M.A. Thesis, University of Canterbury, Christchurch, NZ. 118p.

Flain, M. 1980: Quinnat salmon *Oncorhynchus tshawytscha* (Walbaum) runs 1965-78 in the Glenariffe Stream, Rakaia River, New Zealand. Occasional Publication, Fisheries Research Division, Ministry of Agriculture and Fisheries, Wellington, NZ. (in press).

Frengley, G. A. G. 1979: Water demand and irrigation investment with reference to the proposed Rakaia irrigation scheme. Ph.D. Thesis, Lincoln College, Canterbury, NZ. 254p.

Graynoth, E. 1972: New Zealand salmon angling statistics. *Fisheries Technical Report 83.* NZ Marine Department, Wellington. pp.42-51.

Graynoth, E., Skrzynski, W. 1974: The North Canterbury trout and salmon fishery. *Fisheries Technical Report 90.* Ministry of Agriculture and Fisheries, NZ. 41p.

Hadfield, S. M.; Johnson, R. W. L.; Le Couteur, H. F. J. 1974a: A productivity study of irrigation, Central Plains, Canterbury. Economics Division Report, Ministry of Agriculture and Fisheries, NZ. 84p.

Hadfield, S. M.; Johnson R. W. L.; Le Couteur, H. F. J. 1974b: A productivity study of irrigation, Rakaia-Pendarves-Seafield, Canterbury. Economics Division Report, Ministry of Agriculture and Fisheries, NZ. 78p.

Hubbard, L. J.; Brown, W. A. N. 1979: The regional impacts on irrigation development in the Lower Waitaki. *AERU Research Report 99.* Lincoln College, Canterbury, NZ. 143p.

Huber, D. G. 1973: Water resource development for expanded irrigated agriculture on the Canterbury Plains. *Lincoln Papers in Water Resources 11.* Lincoln College, Canterbury, NZ. 65p.

Hughey, K. F. D. 1980: Hydrological aspects of brown trout management in the Selwyn River system, Canterbury, New Zealand. M.Sc. Thesis, Joint Centre for Environmental Sciences, University of Canterbury and Lincoln College, Christchurch, NZ. 187p.

Hunt, B. W.; Wilson, D. D. 1974: Graphical calculation of aquifer transmissivities in Northern Canterbury, New Zealand. *Journal of Hydrology (NZ) 13 (2)*: 66-80.

Ibbitt, R. P. 1979: Flow report for Rakaia River at Gorge, site 68502 for the period 1957-78. *Water and Soil Science Centre Report WS 11.* Ministry of Works and Development, Christchurch, NZ. 52p.

Ibbitt, R. P. 1980: Flow estimation in an unstable river illustrated on the Rakaia River for the period 1958–1978. *Journal of Hydrology (NZ) 18(2)*: 88–108.

Kear, B. S.; Gibbs, H. S.; Millar, R. B. 1967: Soils of the downs and plains, Canterbury and North Otago, New Zealand. *NZ Soil Bureau Bulletin 14.* Department of Scientific and Industrial Research, Wellington, NZ. 92p.

Kirk, R. M.; Owens, I. F.; Kelk, J. G. 1977: River supplies of coastal sediment in Canterbury and the role of low flows in littoral by-passing. Paper presented at NZ Hydrological Society Annual Symposium, Christchurch, NZ. 9p.

Le Page, D. K.; Ritchie, I. J. 1980: Lower Rakaia irrigation scheme: planning alternatives. *Internal Report 3/80.* Economics Division, Ministry of Agriculture and Fisheries, Christchurch, NZ.

Lord, P. 1979: Lower Rakaia irrigation scheme: spray irrigation survey. Internal Report, Ministry of Agriculture and Fisheries, Ashburton, NZ. 10p.

McDowall, R. M. 1978: "New Zealand freshwater fishes". Heinemann Educational Books, Auckland, NZ. 230p.

Mandel, S. 1974: The groundwater resources of the Canterbury Plains. *Lincoln Papers in Water Resources 12.* Lincoln College, Canterbury, NZ. 59p.

Martin, G. N.; Noonan, M. J. 1977: Effects of domestic waste water disposal by land irrigation on groundwater quality of the Central Canterbury Plains. *Water and Soil Technical Publication 7.* Ministry of Works and Development, Wellington, NZ. 25p.

Morton, H. A. 1978: Environmental and social impacts of irrigation. *In* "Proceedings of Irrigation Conference",

Ashburton, NZ, April 11–13. pp.25–32.
North Canterbury Catchment Board 1974: Rakaia River Management Plan. North Canterbury Catchment Board, Christchurch, NZ. 5p.
NZ Meteorological Service 1973: Rainfall normals for New Zealand: 1941 to 1970. *Miscellaneous Publication 145*. NZ Meteorological Service, Wellington. 34p.
Octa Associates 1976: North Canterbury Acclimatisation Survey. *In* "Annual Report", North Canterbury Acclimatisation Society, Christchurch, NZ. pp.34–71.
Philpott, W. J. L. 1980: Rakaia water use and irrigation development: matching supply and demand for water from the Rakaia River. *Water and Soil Irrigation Report WS114*. Ministry of Works and Development, Christchurch, NZ. 41p. & Appendices.
Pierce, R. J. 1979: Foods and feeding of the Wrybill *(Anarhynchus frontalis)* on its riverbed breeding grounds. *Notornis 26*: 1–21.
Power, C. R.; Broadhead, R. G.; Hutchinson, P. D. 1980: Irrigation demand assessment model (IDAM) – user's guide and technical reference manual. *Water and Soil Science Centre Report WS182*. Ministry of Works and Development, Christchurch, NZ.
Public Works Department 1945: "Water put to work". Issued under authority of R. Semple, Minister of Works, NZ. 40p.
Quin, B. F.; Burden, R. J. 1979: The effects of land use and hydrology on groundwater quality in mid-Canterbury, New Zealand. *Progress in Water Technology 11 (6)*: 433–448.
Rickard, D. S. 1978: Meteorological data 1950–1976. *Technical Report 11*. Winchmore Irrigation Research Station, Ministry of Agriculture and Fisheries, Ashburton, NZ. 34p.
Rickard, D. S.; Fitzgerald, P. D. 1969: The estimation and occurrence of agricultural drought. *Journal of Hydrology (NZ) 8(1)*: 11–16.
Rickard, D. S; Fitzgerald, P. D. 1973: An evapotranspiration model for water balance and irrigation research. Paper presented at NZ Hydrological Society Annual Symposium, Lincoln College, Canterbury, NZ. 17p.
Sibson, R. B. 1963: A population study of the Wry-billed Plover *(Anarhynchus frontalis)*. *Notornis 10*: 146–153.
Smart, G. M. 1978: The development and application of analytical techniques for planning of irrigation systems. Ph.D. Thesis, Lincoln College, Canterbury, NZ. 151p.
Southern Energy Group 1976: Hydro energy and irrigation – Rakaia River concept study. *Report No. 6*. NZ Energy Research and Development Committee, Auckland, NZ. Vol. 1, 90p. Vol. 2, 19p.
Spence, B. L.; Bell, G. S.; Owen, G. 1974: Groundwater flow in the Canterbury Plains between the Rakaia and Ashburton Rivers. Unpublished B. E. (Civil) Study Reports, University of Canterbury, Christchurch, NZ.
Stead, E. F. 1932: "Life histories of New Zealand birds". Search Publ. Co., London. 161p.
Stephen, G. D. 1972: The water resources of the Rakaia catchment. North Canterbury Catchment Board, Christchurch, NZ. 41p.
Stewart, J. D. 1963: The comparative profitability and productivity of a sample of irrigated and non-irrigated farms in the Ashburton-Lyndhurst area of mid-Canterbury, New Zealand. *Publication 1*. Lincoln College, Canterbury, NZ. 22p.
Stuart, R. C.; Tocker, H. H. 1957: Proposed Waimakariri-Selwyn irrigation scheme agriculture report. Department of Agriculture, Christchurch, NZ. 11p.
Taylor, A. R. 1974: Impact of agricultural water usage on the environment. *NZ Agricultural Science 8 (3)*: 120–125.
Thorpe, H. R. 1979: The present status of knowledge of the groundwater resources of the Ashburton-Rakaia region. *Water and Soil Science Centre Report WS165*. Ministry of Works and Development, Christchurch, NZ. 11p.
Turbott, E. G. 1969: Native birds. In "*Natural history of Canterbury*", (ed. by G. A. Knox). A. H. & A. W. Reed, Wellington, NZ. 430p.
Walsh, R. P. 1975: The resources and usage of water in the Rangitata catchment. South Canterbury Catchment Board, Timaru, NZ. 83p.
Ward, W. T.; Harris, C. S.; Schapper H. P. 1964: Soils and agriculture of Ellesmere County, Canterbury, New Zealand. *NZ Soil Bureau Bulletin 21*. Department of Scientific and Industrial Research, Wellington, NZ. 81p.
Water and Soil Conservation Act 1967: Reprinted Act with amendments incorporated, sections 14(3)(d) & 20(5)(c). NZ Government Printer, Wellington.
West, I. F.; Goode, R. H. 1980: A postal sample survey of anglers fishing for sea-run quinnat salmon (*Oncorhynchus tshawytscha*) on the Rakaia River, Canterbury, New Zealand, for the seasons 1973/74 and 1974/75. Manuscript in preparation. Fisheries Research Division, Ministry of Agriculture and Fisheries, Christchurch, NZ.

WATER AND SOIL MISCELLANEOUS PUBLICATIONS

1. Rainfalls and floods of Cyclone Alison, March 1975, on the north-eastern Ruahine Range ($1-00)
P J Grant, N V Hawkins, W Christie 1978

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compiled by Sally F Davis 1978

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compiled by Sally F Davis 1978

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11. Liquid and waterborne wastes research in New Zealand 1978 1980

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G D and J H Egarr in press

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G D and J H Egarr in press

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